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BATS AND THEIR YOUNG.

By Prof. BURT G. WILDER.

EXCEPTING the colder regions, all parts of the world are inhabited by bats. There are many kinds, and they often occur in very large numbers. Probably there are very few persons, young or old, who have not seen a bat. Yet, aside from professed naturalists, it is equally probable that there are still fewer who, from direct observation, could give any accurate description of their appearance or their habits, their structure, or their relations with the "birds of the air," or the "beasts of the earth," to both of which bats bear more or less resemblance.

Nor is this strange; for bats pass the day in caves and deserted buildings, and fly about in pursuit of prey only in the twilight. Much less rapid than that of birds, their flight is so irregular as to render it difficult to follow their course, and in the dusk they are often mistaken for somewhat eccentric members of the swallow family.

Their very aspect is repulsive; they often emit an unpleasant odor; and, worse than all, there is reason for believing them to serve as the vehicle by which the *Cimex lectularius*, that terror of housekeepers, has sometimes gained entrance to habitations where its presence would never have been suspected.

When taken they bite so fiercely that we may be thankful that they are no larger, and that, as a rule, they prefer insects to human beings as food. No tiger could be more violent in its demonstrations or more capable of using its only weapons, the sharp, almost needle-like eye-teeth.

This accounts for the rarity of instances of the domestication of bats, and this, in part, for the difficulty of making any extended observations upon them. Having found recorded but two such cases, I will begin my account of bats in general with a brief history of one individual which I succeeded in taming quite thoroughly. It was

when I was a boy, and the details have escaped me, but the main facts are as follows:

One of our common bats (probably either the "little brown bat," *Vespertilio subulatus*, or the "little red bat") flew into the house one evening and was caught under a hat. It squeaked and snapped its little jaws so viciously that all efforts toward closer acquaintance were postponed until morning.

When uncovered the next day it seemed as fierce as before, but less active in its movements, probably overpowered by the glare of daylight. When touched its jaws opened wide, the sharp teeth were

FIG. 1.—COMMON ENGLISH BAT (*Vespertilio communis*).

exposed, and from its little throat came the sharp steely clicks so characteristic of our bats. Nor did this fierce demeanor soften in the least during the day, and when night approached I was about to let it go, but the sight of a big fly upon the window suggested an attempt to feed the captive. Held by the wings between the points of a pair of forceps, the fly had no sooner touched the bat's nose than it was seized, crunched, and swallowed. The rapidity of its disappearance accorded with the width to which the eater's jaws were opened to receive it, and, but for the dismal crackling of skin and wings, reminded one of the sudden engulfment of beetles by a hungry young robin.

A second fly went the same road. The third was more deliberately masticated, and I ventured to pat the devourer's head. Instantly all was changed. The jaws gaped as if they would separate, the crushed fly dropped from the tongue, and the well-known click proclaimed a hatred and defiance which hunger could not subdue nor food appease. So at least it seemed, and I think any but a boy-naturalist would have yielded to the temptation to fling the spiteful creature out of the window. Perhaps, too, a certain obstinacy made me unwilling to so easily relinquish the newly-formed hope of domesticating a bat. At any rate, another fly was presented, and, like the former, dropped the moment my fingers touched the head of the bat.

With a third I waited until the bat seemed to be actually swallowing, and unable to either discontinue that process or open its mouth to any extent.[1]

Its rage and perplexity were comical to behold, and, when the fly was really down, it seemed to almost burst with the effort to express its indignation. But this did not prevent it from falling into the same trap again; and, to make a long story short, it finally learned by experience that, while chewing and swallowing were more or less interrupted by snapping at me, both operations were quite compatible with my gentle stroking of its head. And even a bat has brains enough to see the foolishness of losing a dinner in order to resent an unsolicited kindness.

In a few days the bat would take flies from my fingers; although, either from eagerness or because blinded by the light, it too often nipped me sharply in its efforts to seize the victim.

Its voracity was almost incredible. For several weeks it devoured at least fifty house-flies in a day (it was vacation, and my playmates had to assist me), and once disposed of *eighty* between day-break and sunset.

This bat I kept for more than two months. It would shuffle across the table when I entered the room, and lift up its head for the expected fly. When traveling it was carried in my breast-pocket.

In the fall it died, either from overeating or lack of exercise, for I dared not let it out-of-doors, and it was so apt to injure itself in the rooms that I seldom allowed it to fly.

I should add that it drank frequently and greedily from the tip of a camel's-hair pencil.

The following bits of bat biography are from White's "Natural History of Selborne," and the "Annals and Magazine of Natural History:"

"Having caught a lively male specimen of the common 'long-eared bat' (*Plecotus auritus*) and placed the little fellow in a wire-gauze cage, and inserted a few large flies, he was soon attracted by their buzz, and, pricking up his ears (just as a donkey does), he pounced upon his prey. But, instead of taking it directly into his mouth, he covered it with his body and beat it by aid of its arms, etc., into the bag formed by the interfemoral membrane. He then put his head under his body, withdrew the fly from the bag, and devoured it at leisure.

"This appeared to be always the *modus operandi*, more or less cleverly performed. Several times, when the fly happened to be on the flat surface of the ground, the capture appeared more difficult, and my little friend was, by his exertions, thrown on his back. The tail could

[1] I did not understand this at the time. If my readers will try it, they will find that it is very difficult to even begin to swallow with the mouth open, and almost impossible to prevent the morsel from descending after reaching the back of the throat.

then be seen turned round, with its tip and the margin of the membrane pressed against the stomach, forming a capital trap, holding the fly, the captor remaining on his back till he had withdrawn the fly from the bag.

"I had no opportunity of observing the action when the bat was in full flight; but, if the insect was captured a few inches from the side of the cage, the mode was the same! When flying, the interfemoral

FIG. 2.—LONG-EARED ENGLISH BAT (*Plecotus auritus*).

membrane is not extended to a flat surface (and appears not capable of being so stretched), but always preserves a more or less concave form, highly calculated to serve the purposes of a skim-net to capture insects on the wing.

"Occasionally, when the bat was sleepy, sitting at the bottom of the cage, nodding his head, a poor, silly 'blue-bottle fly,' no doubt of tender age, and not read in the natural history of the *Vespertilionidæ*, with the greatest confidence walked quietly under the bat, passing nose, ear, and eyes, without danger; but, immediately he touched the sensitive membrane of the bag, it was closed upon him, and there was no retreat except by being helped out of the difficulty by the teeth of the bat.

"I was much entertained last summer with a tame bat which would take flies out of a person's hand. If you gave it any thing to eat, it brought its wings round before the mouth, hovering and hiding its head in the manner of birds of prey when they feed. The adroitness it showed in shearing off the wings of the flies, which were always rejected, was worthy of observation, and pleased me much. Insects seemed to be most acceptable, though it did not refuse raw flesh when offered. . . . I saw it several times confute the vulgar opinion that

bats, when down on a flat surface, cannot get on the wing again, by rising with great ease from the floor. . . ."

So far, we have contented ourselves with treating of bats simply as such, and without reference to their internal structure, their relationship with other animals, or even their differences among themselves; much less have we approached the deeper questions of their origin and destiny—the probabilities as to their ancestry, and the possibilities as to their more or less remote descendants.

In the same way the astronomer may, for a time, speak of a comet only as a certain well-known celestial phenomenon, which may be as obvious to the unaided vision of the ignorant as to his own. But, sooner or later, he cannot refrain from discussing its chemical and physical condition, its course through space, its relations to other comets and to the stars, and, finally, its probable origin from nebulous matter, and its possible transformation into a world like our own.

The comparison may be carried one step farther. For, to the ignorant and superstitious the sudden apparition of a blazing comet has often been a portent of disaster, while even the intelligent shrink with aversion from the flitting bat, and make comparisons with evil spirits.

FIG. 3.—VAMPIRE-BAT OF SOUTH AMERICA (*Vampirus spectrum*).

It must be admitted that most bats are "uncanny" in their aspect, and unfriendly in disposition; while the legends of blood-thirsty vampires have only too much foundation in fact.

But it is only fair to them (the bat family) to admit that the number of species which thus injure men and the larger animals is very small; and that, while all of our own bats, and most of those of other lands, are fierce devourers of insects, and use their sharp teeth for defense against their captors, there are many kinds, especially the larger (Roussettes, etc.), which live almost wholly upon fruits, and are, more-

over, quite good eating themselves. So there should be made a distinction between them as between the venomous and the harmless serpents and the more and the less poisonous spiders.

Perhaps one element of distrust of the bat family arises from their apparent non-conformity to either of the common animal types. The bat seems to be either a bird with hair and teeth, bringing forth its young alive, or a mammal with wings, and the general aspect and habit of a bird. Add to these exceptional features that their attitude, when at rest, is always head downward, and that their legs are so turned outward as to bring the knees behind instead of in front, and we may almost pardon the common dislike of the whole family of bats.

FIG. 4.—FLYING-FOX OR ROUSSETTE (*Pteropus rubricollis*).

We may as well state at once that a bat is really a *mammal;* that is, it agrees with moles, rats, sheep, horses, cats, monkeys, and men, in bringing forth its young alive, and nursing them by milk; in having red blood-corpuscles, which contain no nucleus; in being clothed with hair; and in possessing a *corpus callosum*, that is, a band of fibres connecting the two cerebral hemispheres.

There are other anatomical features which link the bats closely with the moles and shrews and hedge-hogs. Indeed, the bat might be described as a flying mole, or the mole as a burrowing bat.

Twenty years ago one of these phrases might have been as acceptable as the other; for they would have implied only an ideal connection between the forms. But now, when the idea of an actual evolution or derivation of widely-different forms from one another, or from common stocks, is rapidly becoming the fundamental postulate of all biological research, we are bound to inquire whether one mode of expression is not much more likely to be true than the other.

For the solution of this, as of most such inquiries, we must appeal to embryology, to the study of the development of animals, and of the resemblances between the earlier stages of some and the later stages of others.

Our first object is to confirm the conclusion that bats are mammals rather than birds. And here, strangely enough, we find that the matter of *size*, usually regarded as of little moment in zoölogical discrimination, becomes of primary importance. All animals, mammals as well as birds, are formed from eggs. An egg, or ovum, is a cell with special endowments, and capable of availing itself of the peculiar conditions under which it is placed, the first of these conditions being the access of the zoösperms of the male. Now, the eggs of all mammals are small, usually microscopic. The human ovum is about $\frac{1}{120}$ of an inch in diameter.

Therefore, although the yolk or essential part of the egg of a humming-bird may be pretty small, it is far larger than the largest mammalian ovum; while that of the ostrich or the *Epyornis* is simply gigantic in comparison.

Now, I am not aware that the ovum of a bat has ever been examined, but there can be doubt of its minuteness as compared with that of any known bird. Fig. 5 shows, of its natural size, the earliest embryo of a bat I have ever heard of. Its length as it lies is much less than that of a humming-bird's egg. Moreover, since the young bird is developed upon the yolk, and the latter remains of considerable size until very near the period of hatching, and since the yolk of our little bat either has been already absorbed or is too minute for detection, it may be considered that it was much smaller than that of birds.

Finally, the simple fact that the little bat was taken out of the mother already somewhat advanced in development, is clear proof that it is not a bird.[1]

Aside from the absence of yolk, the form of the smallest embryo, above figured, might not determine its mammalian nature; but the remaining figures, however little some of them may resemble quadrupeds, are evidently not birds. The tail is too long (for any bird excepting the *Archeopteryx*); the muzzle is rounded, the feet have five divisions more or less marked, while no bird has more than four toes; and, although the hands may in some cases resemble a bird's wing, yet here too are five fingers, and the wing is evidently an expansion of the hand itself by the elongation and separation of the fingers, rather than a slender hand with feathers attached to the hinder border as with birds.

[1] There are no known birds which normally produce living young; but I have a chicken-like body nearly three inches long, which was developed within the hen. It was shown at the meeting of the American Association for the Advancement of Science, this year. Its exact nature can only be learned after full examination of the structure.

With the more advanced embryos the prominent ear would be conclusive against their avian nature, and the nostrils, where they show, are not those of birds.

We may, then, dismiss from our minds any anxiety as to whether bats are partly birds and partly mammals, and conclude merely that, upon the essential mammalian structure, there have been superinduced features which enable the bat to fly in the air; these, however, no more making it a bird than the form and habit of the whale and manatee render them fishes.

The second question is, whether bats are to be regarded as the progenitors or the descendants of the moles and shrews; or, to put it more accurately (since the idea of derivation does not imply that living species have descended from other living species, but from similar extinct species or from others which combined features since separated in the two forms), is it probable that the existing bats have been produced from original stocks more nearly resembling the moles or the reverse? That the former is the more probable, is indicated upon three grounds:

1. The bat form is peculiar among mammals, and does not, like the *Ornithorhynchus* and *Echidna*, manifest any *internal* structural affinity with birds. There is a much more marked resemblance to the extinct flying reptiles (*Pterodactyli*), but this is probably one of analogy.

2. The embryo bat resembles the ordinary small mammal; the long fingers, the persistence of the web between them, and its continuation from the border of the body and tail, are features of later appearance.

3. In one embryo (Fig. 9), the thinness and prolongation of the muzzle as compared with the lower jaw may be compared with the elongated snouts of the "star-nosed mole" and the "elephant shrew."

I have never had the opportunity of examining the young of moles or shrews. This would be very desirable, and, one would think, not difficult to accomplish.

Figs. 5 to 11 are intended chiefly to show the gradual development of the limbs, so the other parts are drawn with less detail, and no attempt is made to elucidate the manner of formation of the face from the visceral arches.

The series begins with Fig. 5. Here the body is simply an elongated mass, longer and rounded at the head end, and tapering at the other extremity. It is twisted upon itself, as is often the case with young embryos. The yolk-sack and membranes are not well preserved, and are not shown at all in the figure. This embryo may be regarded as quite small for even a bat. The limbs have not appeared, so the tail does not form a distinct prolongation. (The lower figure is of natural size; the upper is enlarged five diameters.)

In Fig. 6 the arm (*ar*) and leg (*pes*) project as little flat pads from the sides of the body. There is no sign of subdivision into fingers and toes, and very little difference between the two limbs. It is worth

Fig. 5.

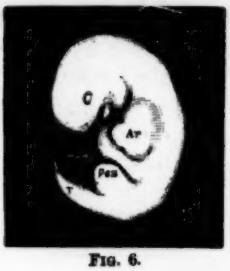


Fig. 6.

Fig. 7.

Fig. 8.

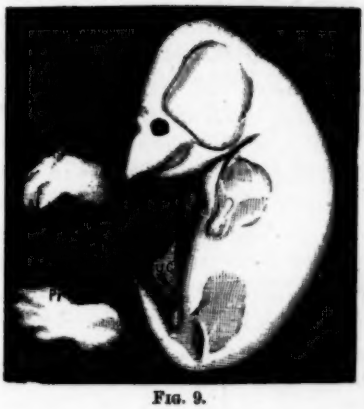


Fig. 9.

Fig. 10.

Fig. 11.

Embryo Bats. All, excepting Fig. 11, enlarged 5 diameters.

Explanation of Plate.[1]

Figs. 10 and 11 from the little brown bat (*Vespertilio subulatus*), the others from a Brazilian species (*Nyctinomus Brasiliensis*); Fig. 11 and the smaller part of Fig. 5 are of natural size. All the others are enlarged 5 diameters; that is, 25 areas. The lettering is uniform, as follows: *u c*, umbilical cord; not seen in 5 or 8. *H*, head; *T*, tail; *Ar*, armus or anterior limb; *Pes*, foot; *P*, pollex or thumb, the anterior digit of the manus; *Pr*, primus or great-toe, the anterior dactyl of the pes, which becomes the *outer* in the older bats, but is the *inner* with most animals; *W*, web, the fold of skin which connects the digits with each other and with the leg and margin of the trunk; *C*, calcar, a spur-like process from the heel, serving to extend the web which reaches between the legs and the tail; *Ear*, the ear; in Fig. 7 *H* is the heart; in Fig. 10 *A* is the rounded prominence corresponding to the cerebral hemispheres which are developed from the anterior cerebral vesicle; *M* represents the optic lobes, formed from the middle vesicle; *N*, nostril; *Mo*, mouth; *E*, elbow; *K*, knee. For further explanation, see the text.

[1] Figs. 5 to 11 were all drawn and engraved from nature by Mr. Philip Bernard.

noting, however, that the manus is already a little the wider and more prominent.

In Fig. 7 the manus is not only larger but has protruded so as to display the wrist and elbow regions, and a slight prominence upon the anterior border marks the position of the thumb (pollex). In these three specimens I have not as yet found the ear, but in 3 and 4 the eye is quite apparent.

In Fig. 6 the ear is a triangular flap, as in most early mammalian embryos.[1]

The manus and pes have enlarged and present shaded portions corresponding with the thinner tissue between the finger and toes. In the former this is to become the web; in the latter it is wholly removed so as to leave the toes free. The muzzle is partly covered by the manus, but it is already somewhat pointed, as in the next figure.

In Fig. 9 the manus and pes of the left side are shown as if removed from the trunk, so as to expose the flat and prominent muzzle. The ear is a large flap, but still projects forward so as to cover the opening. The pollex has separated from the other digits, and the latter are elongated and bent downward. The pes is longer and the signs of subdivision more distinct. A web connected the limbs and the trunk as in the older specimens, but it was somewhat torn, so that the exact extent could not be determined, and I preferred to wait for a better specimen to show it.

The specimens above described were taken from a Brazilian species, *Nyctinomus Brasiliensis* (which is also found in this country). Figs. 10 and 11 were from the common "little brown bat" (*Vespertilio subulatus*). As might be expected, the increasing limbs are packed about the body more or less irregularly. But in Fig. 10 the limbs of the two sides are placed with almost exact symmetry so as to cover the face and the body. One eye is covered, the other peeps out over the index-finger. The ears are firmly held down by the thumbs, and one of the nostrils is partly hidden by the web. The lower part of the trunk and the tail are bent upward, and the knees are thrown outward so as to bring the great-toe (*pr*) upon the outer instead of the inner side. The whole suggests an effort upon the part of the embryo to not only occupy the least possible space, but also to screen itself from observation, and neither see, nor hear, nor smell.

In Fig. 11 is shown an older embryo, of natural size, outspread so as to display the characteristic features of bats; the greatly-elongated fingers; the separation of the thumb; and the extension of the web, with the reticulated arrangement of vessels and nerves upon it. This nervous expansion seems to enable bats to perceive the proximity of bodies by the change in the pressure of the air.

[1] It remains to be seen whether the seals, whales, manatee, and dugong, have a pinna in the earlier stages, and afterward lose it. Upon the earliest embryo of a manatee yet known, see a paper by the writer in *American Journal of Science*, August, 1875.

THE SIZE OF BAT FAMILIES.—It is not known that bats make a nest like birds, or that they have any other way of caring for their young than by carrying them hanging to their fur whether during flight or while suspended at rest by the legs.

So we might naturally infer two things: first, that the young bats would be born in a somewhat advanced condition so as to be able as soon as possible to shift for themselves; and, second, that the number produced at a birth would be small.

The former inference would seem to be true, judging from the large size of the little bats before birth, and the rarity of the capture of the mothers with young. In one case the two unborn young weighed two-thirds as much as the parent, and the average of twenty individuals gave the weight of the young as four-tenths that of the parents.

Upon the second point it is stated by Van der Hoeven ("Handbook of Zoölogy," vol. ii., p. 731) that "bats commonly produce one or two young ones at a birth;" but he does not say upon how many observations the conclusion is based.

Prof. Owen ("Comparative Anatomy of Vertebrates," vol. iii., p. 730) records two observations of bats (*Vespertilio emarginatus* and *V. noctula*), with each one young, and concludes that this is commonly the case with all bats.

A collared fruit bat (*Cynonycteris collaris*) produced a single young February 27, 1870, and a second April 7, 1871.[1]

In Jamaica Mr. Osborn observed several females of *Molossus fumarius* and *Monophyllus poeyi*, with each one young.[2]

The same observer mentions two other species (*Macrotus Waterhousii*, and *Monophyllus Redmanii*), without specifying the number of young; but we may infer that, as in the other cases, each female had but one.

In a single female of an undetermined Brazilian species I have found one young; and in each of forty females of the *Nyctinomus Brasiliensis* (from Brazil) a single young.

These are certainly facts in corroboration of the opinions of Owen and Van der Hoeven, but let us not be hasty in generalizing from them respecting all bats.

In June, 1874, there were brought to me twenty females of the "little brown bat" (*Vespertilio subulatus*). Each was found to contain *two* little bats in various stages of development.[3]

Finally, Prof. Putnam, of the Peabody Academy of Science, has kindly allowed me to examine two females of the *Lasiurus noveboracensis* taken in Massachusetts, on each of which were *three* young bats.

The foregoing observations indicate that, while one is the more

[1] P. L. Sclater, "Proceedings of Zoölogical Society, 1870, 1871."

[2] "Proceedings of Zoölogical Society, 1865," p. 81.

[3] I have since seen a bat of another species, to which were clinging two young.

common number of young produced by bats, two and three may occur. More extended inquiry may show that these larger families are less rare than now appears, and even that as many as four young may be produced at a birth. For while bats are usually credited with only two nipples, an extra pair exists upon the *Lasiurus noveboracensis*.

The uniformity in number with each species is very striking. Twenty-two of one species had each two young, while forty of another had each one.

In the former case the young were placed one on the right and the other on the left of the body. But in the latter case the single young was invariably on the right side; while, in the single specimen of the undetermined Brazilian bat, the young was on the left side.

Equally striking with the above facts is the isolation of the females with young. Among forty-three *Nyctinomus Brasiliensis* was but a single male. No males were found near the twenty-two *Vespertilio subulatus*. Osborn says that, of *Molossus fumarius*, all of one large lot were males; while at another time, in a large hollow tree, he found in one cavity about one hundred males, and in a second about the same number of females, with "apparently a few males here and there."

Evidently there is much to be learned respecting the domestic and social economy of these animals. Perhaps the males gather food for the females.[1]

Perhaps the most important fact, from a practical point of view, is that of the power of the mother-bats to carry such a weight of young in addition to their own. Yet, so far as I know, all estimates of the extent of wing and size of muscle, which would be necessary to enable a man to fly, have been based upon the idea that the only flying mammal is a fair standard.[2]

These estimates should be corrected so as to conform to the fact that a bat can fly with nearly double its ordinary weight. Even this may not encourage us to hope for a future race of flying-men. But it renders it worth considering whether a man, naturally slight of frame, with small head, could not so far reduce his weight by a flesh diet, and by the amputation of his legs, as to enable him, by special cultivation of his pectoral muscles, to work effectively a pair of wings less extensive than those now supposed to be required.

[1] The writer has not been able to examine the development of bats with the nasal appendages. He would be glad to receive information upon the habits of bats with young, and to exchange the latter for specimens of *Amphioxus*.

[2] Harting ("Archives Néerlandisches," iv.) calculated that a bat the size of a man would require wings two and a half metres long, and with a surface of one and a half square metre.

INSTINCT AND INTELLIGENCE.[1]

By Prof. JOSEPH LE CONTE.

WHAT is instinct? What is its relation to intelligence? These questions form the subject of my lecture to-day.

Many persons would probably object to this subject being treated at all in a course of physiology. Many persons doubtless think that these are questions for the psychologist, and not for the physiologist. But I think you have already perceived, in the course of these lectures, how difficult, yea, impossible, it is to sharply separate these two departments. As between all other departments of science, so also between these, there is a border-land, which is common ground. The physiology of the brain is that common ground.

The precise relation of physiology to psychology it is extremely difficult to adjust. As there are two opposite errors in regard to vital force—one, the old error of regarding this force as something innate, underived, unrelated to other forces of Nature; the other, the new error of regarding it as nothing but ordinary physical and chemical forces, and thus *identifying physiology with chemistry and physics*—so also on this subject there are two opposite errors: one the old error of regarding mental forces as wholly unrelated to and underived from vital forces, and psychology, as wholly disconnected from physiology; the other, the new error of regarding mental phenomena as connected with the brain in the same clear and intelligible way that functions are connected with organs, and *thus identifying psychology with physiology*. But, as in the case of vital force, there is a truer view, viz., that which regards this force as indeed correlated with other lower forces and derived from them, but, nevertheless, as a very distinct *form* of force or cosmic energy, producing a very distinct and peculiar group of phenomena, the knowledge of which constitutes the science of physiology; so also, on the subject of mental force, there is a truer view which comprehends and embraces the extremes mentioned above.

Let me briefly explain my views on this subject. In recent times physiology has indeed made great, and to many startling, advances in the direction of connecting mental phenomena with brain-changes. Physiologists have established the correlation of physical and chemical with vital forces, and probably of vital with mental forces. They have proved in every act of perception the existence of a vibratory thrill passing along the nerve-cord from sense-organ to brain; and in every act of volition a similar vibratory thrill from brain to muscle; they have even determined the velocity of this vibratory thrill, and find it, to the surprise of those who identify nervous force with elec-

[1] A Lecture to the Class in Comparative Physiology in the University of California.

tricity, only *about* 100 *feet per second.* They have also established the fact of a chemical or molecular change in the brain corresponding with changes in mental states; and with great probability, also, a quantitative relation between these corresponding changes, and therefore a *relation between them of cause and effect.* In the near future we may do more: we may localize all the faculties and powers of the mind in different parts of the brain, each in its several place, and thus lay the foundations of a scientific phrenology. In the *far-distant future* we may do even much more: we may possibly connect every different kind of mental state with a different and distinctive kind of molecular or chemical change in the brain; we may find, for example, that a right-handed rotation of atoms is associated with love, and a left-handed rotation with hate. We may do all this, and much more. We may push our knowledge in this direction as far as the boldest imagination can reach, and even then we are no nearer the solution of this mystery than before. Even then it would be impossible for us to understand *how* brain-changes can produce even the simplest psychological phenomena such as *sensation, consciousness, will.* By no effort of the mind can we conceive *how* molecular *motion* can produce *sensation* or *consciousness.* The two sets of phenomena belong to different orders—orders so different, that it is simply impossible to construe the one in terms of the other.

It is not thus with other groups of phenomena in relation to one another. The phenomena of motion, heat, gravity, light, electricity, chemical affinity—yea, also of vitality—have been, or may be, construed in terms of each other, and all in terms of *molecular motion.* Whether our present theories on this subject be true or not, may admit of doubt; but a true theory is at least conceivable; all these may conceivably be reduced to the same order. But no amount of knowledge nor strength of imagination will in the least degree help us to understand the mysterious causal relation between the molecular changes in the brain and the corresponding effects in the mind, or between changes in the mind and corresponding changes in the brain.

I wish to put this as clearly and as strongly as I can. Suppose, then, an *infinite human* knowledge—infinite in *degree*, but human in *kind;* suppose, in other words, an absolutely perfect science, such as was conceived and admirably expressed by Laplace—a science which had completely subdued its whole domain and reduced it to the greatest simplicity, so that the whole cosmos and its phenomena is expressed by a single mathematical formula, which, worked out with positive signs, would give every phenomenon which would ever occur in the future, or with negative signs every event which had ever occurred in the past. Even to such an infinitely perfect science the causal relation of molecular motion on the one hand to sensation, consciousness, thought, and emotion on the other, or *vice versa*, would still be utterly unintelligible. Like the essential nature of matter, or

the ultimate cause of force, this relation lies outside the domain of science.

But, admitting this chasm which cannot be bridged—admitting the distinctness of psychology and physiology, a distinctness far greater than exists between any other two departments of science—still there can be no doubt that the changes in the brain and in the mind correspond with each other in the strictest manner. There can be no doubt that we have here two parallel series running side by side with corresponding terms, and that every change in the terms of one series is associated with a change in the corresponding terms of the other series. Whichsoever we take as cause, and whichsoever as effect, the correspondence is undoubted. This much seems certain, and this is sufficient to show that a knowledge of the terms of one series must throw light on the order of succession in the terms of the other series. In a word, *physiology*, as the simpler and more fundamental science, *must form the only true basis of a scientific psychology.*

Again, as anatomy only became scientific by becoming *comparative* anatomy, i. e., by the study of the *structure* of organisms in their relation to each other, or as connected by the law of evolution; as physiology, too, only became really scientific by becoming *comparative* physiology; i. e., by tracing the gradual evolution of organic *functions;* even so psychology can never assume the rank of a science until it becomes *comparative* psychology; i. e., until it adopts the comparative method, until it studies the different grades and kinds of mentality in their relation to each other, and connects them all by the law of evolution.

So much I have thought it necessary to say in order to show the importance of my subject, and its close connection with physiology. I now pass on to the subject itself.

It is well known that many of the lower animals, especially certain species of insects, perform acts perfectly adapted to accomplish results, and that *without previous experience and without instruction.* Often the results attained are of a very complex character; results which could not be attained by ourselves except by the exercise of high intelligence, aided by much experience. The extraordinary capacity by which these results are reached with such unerring certainty is called *instinct.*

I need hardly refer you to examples: You are all familiar with the wonderful instinct of the common honey-bee; their organized communities with perfect division of labor, the precision with which they make their honey-cells on perfect mathematical principles, the honors paid to their queen, their care of her eggs, their wise distribution of food to the larvæ, both its quality and quantity, and the form and size of the containing cells being varied according to the function and even to some extent determining the character of the perfect insect, whether drone, or queen, or worker. You are already familiar with

all this and much more which I cannot stop to recapitulate. You are also doubtless familiar with the still more wonderfully organized communities of ants, with their queens, their domestic laborers, and their warriors. You have heard of, if you have not watched, their marauding excursions, their fierce but well-ordered battles, the triumphal return of the victors laden with spoil, and with captives whom they reduce to the condition of domestic servants. I barely mention these examples because they are familiar to all, but I must describe more fully one case of instinct from the same family, which is probably less familiar to you and yet no less wonderful: I refer to the case of the common mud-wasp or clay-dauber.

These insects do not form organized communities, and therefore have no neuters or workers, but each female works for herself. Neither does she feed her young as do bees and other wasps, but provides appropriate food in abundance, and leaves them to themselves. But the mode of building her cells and supplying the appropriate food exhibits a marvelous wisdom. She gathers wet clay in pellets about the size of a duck-shot and commences to build. Going and coming from her clay-quarry to her work, with great patience, industry, and skill, she builds two or three cells side by side, two or three inches long and about half an inch in diameter. When finished she proceeds to fill them with food. For this purpose she attacks all varieties of spiders, stings them, plunging her sting with the greatest precision directly into the principal nerve-ganglion, and, after laying an egg in the body of each, carries them off and packs them away in the cells, until these are completely full, then seals them with clay and leaves them. In due time the eggs are hatched, the larvæ feed upon the spiders, until they become perfect insects, and cut their way out of the cells.

Observe, then, first, the walls of the cells must be thin and composed of porous materials, otherwise the eggs could not hatch, nor the larvæ continue to live, for want of oxygen; second, the spiders must be *helpless but not dead.* If they were dead they would decompose or else dry up before they could be used as food. If, on the other hand, they were alive and active, they would destroy each other, and the contained eggs, and perhaps escape from the cell. But the poison is so adjusted as to quantity, and probably as to the place of insertion, as to produce a state of complete helplessness, a deep *and permanent coma:* the spiders are as it were chloroformed by the poison. If touched or irritated, they move only enough to show that they are not dead. As a boy I have many times watched these wasps gathering their materials, building their cells, gathering their food-supply of spiders. I have many times broken open their finished cells and found them full of spiders in the condition described. If one desires to study spiders, he can gather more varieties in one day, by breaking open the cells of mud-wasps, than in a year in any other way.

Now, such actions performed by man would show high intelligence and much experience; and yet we cannot attribute such intelligence to these insects, because their actions in other directions and under other and new conditions exhibit but a very small amount of intelligence; we are compelled to attribute these wise actions to another and somewhat different faculty, which by way of distinction we call instinct. Let, us then, contrast these two faculties (if they may be so called) and show their distinctive features:

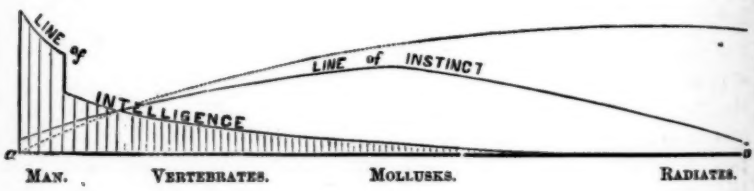
1. *Intelligence works by experience, and is wholly dependent on individual experience for the wisdom of its actions.*—Wisdom in this case is a product of two factors, intelligence and individual experience. Intelligence alone produces nothing. Experience alone is equally valueless. With a given intelligence the product will vary as the experience, with a given amount of experience the product will vary as the intelligence. Thus intelligence works by experience to attain wise results. On the contrary, instinct is wholly independent of individual experience. The young bee or mud-wasp, untaught, works at once without hesitation, with the greatest precision and in the wisest manner, to accomplish the most marvelous results. Like the reflex function of the nervous system, and like the still lower organic functions of secretion, excretion, circulation, respiration, etc., *the wisdom and precision of its actions seem to be the result of structure*, though unlike these the actions are not removed from the sphere of consciousness and will, if we call it intelligence; then it is not *individual* intelligence but *cosmic intelligence*, or the *laws of Nature* working through inherited brain-structure to produce wise results.

2. *Intelligence belongs to the individual, and is therefore variable*, i. e., *different in different individuals, and also improvable in the life of the individual by experience.*—Instinct *belongs to the species*, and is therefore the same in all individuals and unimprovable with age and experience. It is true that close observation would probably detect a slight difference in the skill of different bees, and slight improvement with age, in some more than others, but this must be accredited to the individual, not to the inherited element, i. e., to the small margin of intelligence which undoubtedly exists in these animals.

3. *Instinct in its sphere is far more perfect and unerring than intelligence.*—It makes no mistakes, because determined by structure, not by imperfect knowledge.

In a word, intelligent conduct is *self-determined* and becomes wise by individual experience. Instinctive conduct is *predetermined in wisdom by brain-structure.* The former is free, the latter is to a large extent automatic; the one is like the voluntary locomotion of the higher animals, free to turn whither it likes, but liable to mistakes and stumblings and hurtful falls; the other like the motion of an engine laid upon a track which bears it swiftly and surely to its destined goal.

I have given, thus far, only a few very conspicuous examples of instinct, in order the more clearly to contrast this faculty with intelligence. I might have added many other conspicuous and well recognized examples, such as the migrations and nest-making of birds, the dam-building of beavers, etc. But we would have a very imperfect notion of the wideness of the operation of instinct if we confined ourselves to these conspicuous cases. Instinct in a less remarkable degree is *universal* among animals, including man himself. But what is universal in the popular mind creates no surprise, attracts no attention, and seems to need no explanation; yet it is these very universal and therefore unobserved phenomena which are the most instructive to science. Not only the action of bees and ants and wasps, not only the migrations and the nest-making of birds and the dam-building of beavers, must be accredited to instinct, but also all *complex voluntary motions which are performed without experience.* Such, for example, in many animals are the acts of running, swimming, flying, walking, and standing, etc. Yes, even the simple act of *standing* or walking is really a marvelous feat in balancing—requiring the nice adjustment and perfect coördination of perhaps a hundred different muscles. Even the simple voluntary act of sight (looking) requires the most exquisite adjustment of the optic axes, the lenses, and the iris. These complex actions are acquired by *us* by *experience*, though there is doubtless also, *even in us, a large inherited element*, an inherited capacity by which we acquire them with comparative facility. But the new-born ruminant quadruped or gallinaceous bird *stands* and *walks* and *uses the eyes at once, without experience.* The power to coördinate these muscles, and to accomplish these complex and difficult actions, is wholly inherited, not acquired.[1]



Thus defined, intelligence and instinct are not mutually exclusive, as some seem to suppose: the one is not simply a characteristic of man and the other of animals, but they coexist in varying relative proportions throughout the animal kingdom. As a broad general fact, in going down the animal scale we find that *instinct varies inversely as intelligence.*[2] The accompanying diagram expresses in a general way this relation. If the line *a b* represents the animal scale from

[1] "Instinct in New-born Chickens." *Naturalist*, vol. vii., pp. 300, 377, 384.

[2] As we are not dealing here with measurable quantities, of course I do not use the expression "varies inversely as" in a strict mathematical sense.

man down to the lowest radiate, and upon this as abscis we erect ordinates representing the degrees of intelligence, then by connecting these ordinates we develop what might be called the *line of intelligence*. This line, as is seen, rapidly descends from the higher to the lower races of man, then makes a sudden fall from the lowest races of men to the highest species of monkeys, and thence gradually descends until the ordinates of intelligence become insensible, though they probably still exist down to the lowest point, *b*. If in a similar way we construct a line of instinct, it would probably rise as we pass down through the lower races of men and through the animal scale, reaching its maximum about the middle of the series among insects, and again declining to the end. If, however, we were to construct a third line representing the relative amounts of these two, i. e., the *proportion of instinct to intelligence*, it would probably be a continuously rising curve something like the dotted line in the diagram. The quotient of instinct divided by intelligence, of acquired wisdom divided by inherited wisdom, constantly increases as we go down the scale.

Such, then, is the nature of instinct, and such its general relations to intelligence. But the most important question still remains. How was this wondrous faculty acquired? Whence did it come? How is it derived? In a word, what is the true theory of the *origin of instinct?*

THE ORIGIN OF INSTINCT.—The *old* theology disposes of the above question, as she does so many others, in the most summary way. According to her, instincts are not acquired or derived at all. They are miraculously given in perfection to the first individuals of the species, to each species its several kind. But this explanation cannot satisfy Science. It simply places the question beyond her domain. To science Nature is a continuous chain, and her mission is to recover every link. To her a true explanation of any phenomenon consists in connecting it with other phenomena most nearly allied to it. A scientific explanation or theory of instinct must connect it with intelligence on the one hand and the lower phenomena of the nervous system on the other—must show how all these several capacities are evolved the one from the other—must bring them all under the universal law of evolution.

This, it is admitted, is no easy task. The wonderful instincts of some animals have always been regarded as one of the greatest objections to the theory of evolution. The origin of instinct is reckoned one of the hardest nuts for evolutionists to crack. The subject is indeed an obscure one, but recently some light begins to break. The task is indeed a hard one, but I believe we begin to understand in what direction, at least, we must work. The question is yet far from solved—we are yet in much perplexity, but I think we hold the thread which must eventually lead us out of this labyrinth. I have thought much for many years on this subject, and I now give you the views

which have gradually grown up in my mind. Others, I observe, perhaps nearly all evolutionists, are thinking in much the same direction, but I have not yet seen any distinct presentation of the subject.

The movements of the animal body, you will remember, are divided into two great groups, the voluntary and the involuntary or reflex. But between these extremes there are undoubtedly many intermediate terms connecting them. Thus is it in all our science, and still more in our systematic teaching of science. *Our* distinctions are far more trenchant than the distinctions in Nature. It must and ought to be so, for we must get firm hold of the types first, and then we are prepared to study the intermediate gradations. Of the intermediate terms in this case there are *two* which are quite distinct. Including the extremes, therefore, we have four kinds of animal movements:

1. *The perfect voluntary movements.*—These require the full, constant, and immediate exercise of the will; and, when the movement is complex, requiring in addition the whole thought and attention fixed, often painfully fixed, on the movement. In this category are nearly all movements when accomplished for the first time.

2. *Habitual movements.*—These are *semi-volitional.* They are removed from thoughtful attention, from immediate and painful effort of the will. A general superintendence only of the will is necessary. When any thing goes wrong the mind takes cognizance and corrects it by direct act of the will, and the movement falls, for the time being, into the first category; but otherwise the thoughts and attention may be directed to something else. These are, therefore, to some extent, automatic. Such are, in man at least, the movements in walking, flying, swimming, speaking, playing on a musical instrument, etc. These were, in all cases, at first movements of the first kind, but fell into the second category by *repetition.* They are *acquired*, therefore, wholly by *individual experience.*

3. *Instinctive movements or acts.*—These are still farther removed from the category of the first group. They are *removed*, not only from thoughtful attention, but *also from indvidual experience.* If we compare them with habitual acts, they are *inherited habits.* They are evidently the result of *inherited brain-structure*, but they are not yet wholly removed from the sphere of consciousness and will. Such are the actions of bees and other insects already described.

4. Lastly, *Reflex movements.*—These are wholly automatic. They are wholly removed not only from thoughtful attention and individual experience, but also from consciousness and will. These are therefore the extreme type of movements determined with the greatest precision by inherited structure of the nervous centres. Such are the movements of the heart, the stomach, the intestines, etc.

Now, of these four kinds of acts, 1 and 2 and 3 are evidently formed the one from another, i. e., 2 from 1 and 3 from 2. The fourth I cannot account for in a similar way, for it must have preceded all the

others. And this convinces me that there is yet a higher philosophy on this subject which I have not reached.

Formation of Habits.—We are all familiar with this process. A movement or series of movements at first painfully difficult, and requiring the whole thought and attention, by repetition become so easy and semi-automatic that attention is no longer necessary. The most remarkable examples of these, such as walking, speaking, and the like, probably belong partly to the third category; the capacity for these is partly inherited. Playing on a musical instrument is therefore a better example. We all know the painful attention necessary at first, and the ease and rapidity of the most complex movements attained by practice. Now, by what means, anatomical or physiological, do these at first difficult movements become by repetition easy? The answer in general terms seems to be this: Every volitional act is attended with a change in the brain, which, however, is slight, liable to be effaced by subsequent changes, and therefore *evanescent.* If the same act, however, be repeated many times, the change becomes deep and *permanent*—becomes *petrified in brain-structure;* and this structure, whatever be its character or its seat, determines the appropriate acts with precision. It is as if every volitional act produced a faint line, liable to be erased, on the tablet of the brain; by running over the same lines many times, these are deepened into grooves and finally into *ruts*, and motion in these becomes easy and certain because the ruts guide the motion instead of the will. Thus repetition produces structure and structure determines habit.

Formation of Instincts.—The structure produced by repetition of voluntary acts, and which, as we have seen, determines habits, by the law of inheritance is transmitted in a slight degree to the next generation. I say in a *slight degree* only, because inheritance is from the whole line of ancestry and not from the immediate parents alone. The inheritance from the immediate parents is greater, it is true, than from any *one* of the series of previous generations, but infinitely less than the *sum* of inheritances from *all* previous generations. The structure may be regarded, therefore, as transmitted in an almost effaced condition. If the same acts are not repeated, the lines of structure are soon wholly effaced by new lines running across the tablet in all directions; but if they are repeated the same lines are deepened with greater ease and certainty than before; the structure becomes still more decided, the habit still more fixed. This more deeply-engraved structure is again partially transmitted to be again strengthened in the next generation—the engraved plate is retouched and the lines deepened. Thus with every generation the sum of inheritance becomes greater because from a greater number of preceding generations; with every generation the effacement by transmission is less, and the deepening by repetition is greater, until finally a highly-differentiated structure is formed, and *perfectly transmitted*—a structure

with lines so deep as to determine the direction of conduct with the greatest certainty. *Then habit becomes instinct.* The individual no longer forms the structure, but inherits it ready formed. The actions are no longer learned by practice, they are already predetermined by the inherited structure.

We see illustrations of this process in the artificial formation—the deliberate manufacture—of instincts in domestic animals by human training and human selection. We know that the instincts of the pointer and the shepherd's dog have been formed in this way. The great ancestor of all the pointers, before he was a pointer, was trained with much coaxing and many beatings to do certain things. The result was doubtless any thing but satisfactory. Still a habit was formed, and, as we must believe, a corresponding brain-structure. The pups of this dog were again trained, still with difficulty, but with less difficulty than before, because the habit-structure was partially inherited. The best-trained of this generation are selected, and their pups again trained. The process is still easier, because the habit-structure is more completely inherited, and the result is more satisfactory, because the structure is more decided. Thus the improvement goes on from generation to generation, until finally, in the purest bloods, i. e., those having the longest line of well-trained ancestry, without mixture with effacing bloods, little or no training at all is required; the habit-structure is almost perfectly transmitted. Perhaps in this case transmitted habit never becomes perfect instinct; probably the best-blooded pups still require training. But this is because the process has not been continued long enough, the breeding has not been true enough, and the selection careful enough.

Now, if pointers or shepherds' dogs should become wild, their instincts would quickly be destroyed by natural selection, because they are not useful, but, on the contrary, hurtful, in the wild state. But, suppose they were useful in the struggle for life, then the habit thus acquired would be transmitted, and become strengthened with every generation, until it would become as perfectly fixed and invariable as any, even the most perfect instinct.

Now, it is precisely in this way that the wonderful instincts of bees and ants and the wonderful instinctive coördination of muscles in ruminants and gallinaceous birds have been formed, except that in these cases *natural* training and *natural* selection have operated instead of *human* training and *human* selection. The great ancestor of all the bees, before the distinctive characters of the bee yet existed, was doubtless destitute of the wonderful instincts which we now find. These have been gradually formed and improved from generation to generation through many hundred thousands of years.

It is difficult to imagine, much more to express, all the steps of this process. I will, therefore, illustrate it in the following manner: We have seen that wise conduct is a product of intelligence and expe-

rience. Evidently, therefore, great wisdom may be attained even with small intelligence, if only the experience be proportionally great. Wisdom increases with experience without limit, if only the plasticity of the brain, or its capacity to receive and retain impressions, remain unimpaired. Now, suppose a number of the ancestors of the bees many hundred thousand years ago, before these specific instincts were developed; suppose, further, that these *individual insects had continued to live from that time to this*, and retained their brain-plasticity unimpaired. Even with the smallest modicum of intelligence, such instincts would, by experience, slowly improve their habits from year to year, from century to century, from millennium to millennium, until they would reach a surprising skill in accomplishing the most complex results. This would be *habit*, not instinct. The habit so long forming, so useful, and therefore so invariable, would of course be embodied in a very decided brain-structure. Now, precisely the same result is far more perfectly reached by the experience of many generations transmitted and accumulated by the law of inheritance. I say *more perfectly*, because of the natural selection of only the fittest in each generation.

Thus we see that instinctive wisdom is also the result of experience, but it is *ancestral*, and not individual experience. Individual experience is first fixed in habit, and then habit is transmitted and petrified in instinct. In a note published in the *Philosophical Magazine*, April, 1871, I speak of instinct as "*inherited experience*." I did not then know that I had been anticipated by a few months by Hering ("Archives des Science," February, 1871), who calls instinct "*inherited memory*." These are but different modes of expressing the same idea. Intelligence works by *individual experience* treasured in *memory;* instinct by *racial* or *communal experience* treasured in *inherited structure*. But memory is evidently the result of brain-structure formed by experience; therefore also is instinct *inherited memory*. Again, knowledge is remembered experience; therefore is instinct also *inherited knowledge*. Thus *experience, memory, knowledge*, things which seem to us so indissolubly connected with *individual identity*, are also sometimes inherited.

Thus, then, the sum of experience and the mental wealth which is accumulated by experience consists of two parts, individual and inherited. In man the *individual* acquisition is large, and the inheritance is comparatively small. In the lower animals the individual acquisition is small, while the inheritance is large. In bees the wealth is almost wholly inheritance.

We now easily see why intelligence varies inversely as instinct—why high intelligence seems incompatible with remarkable and invariable instinct. It is because, with high intelligence, actions are *so varied*, in different individuals and in different generations, that it is impossible that their results should accumulate and become petrified in structure. But, in the lower animals, the conditions of life are nar-

row, the habits necessary for successful struggle for life *run in few lines*, and these lines become deepened with every generation, until they become, as it were, petrified in brain-structure.

Instinct, therefore, is accumulated experience, or knowledge of many generations fixed permanently and petrified in brain-structure. All such petrifaction arrests development, because unadaptable to new conditions. They are found, therefore, only in classes and families *widely differentiated from the main stem of evolution*, from the lowest animals to man. Instincts are, indeed, the flower and fruit at the end of these widely-differentiated branches, but flowering and fruiting arrest onward growth.

Now, there is also a *social* evolution. The organic evolution, which found its term in man, is continued by man in social evolution. It is natural, therefore, to look for the corresponding phenomenon in the higher sphere of social evolution. I believe we find it in the phenomenon of *arrested civilizations*, of which nearly all barbarous and semi-civilized races are examples, but the Chinese and Japanese are the most conspicuous; and also, perhaps, to some extent, in the phenomenon of dead civilizations, of which the Greek and Roman are the most conspicuous. Nations *isolated* and *breeding true*, i. e., without mixture with other nations, gradually assume fixed customs and habits which become enforced, and therefore perpetuated by law, and finally *petrified in national character*. The result is often marvelous development, but extremely *limited*. Here, again, perfect flower and fruit destroy growth. Here again, also, it occurs in a type or branch widely differentiated from the main stem of social progress. This explains one of the advantages of cross-breeding, or mixing of varieties within certain limits of national varieties, if not of races.[1] It confers plasticity; it prevents the formation of fixed national character, and the consequent arrest of progress by petrifaction.

Let us hope, then, that the growing tree of society will always remain an *excurrent;* that its upshooting stem shall never lose itself in mere branches; that its terminal bud shall never fail, but always continue to grow. Its branches may flower, and fruit, and die, or cease to grow, but the trunk stretches ever upward and bears each successive flowering branch higher and still higher. Doubtless the ideal of humanity is that all right actions are spontaneously or instinctively performed, and all important truths intuitively or instinctively known; but this is and must be an unattainable ideal; for, this condition reached, how shall we any longer aspire?—the terminal bud flowering, how shall the tree continue to grow? Human nature must never petrify into instinct; inherited wealth must never supersede the necessity of individual acquirement.

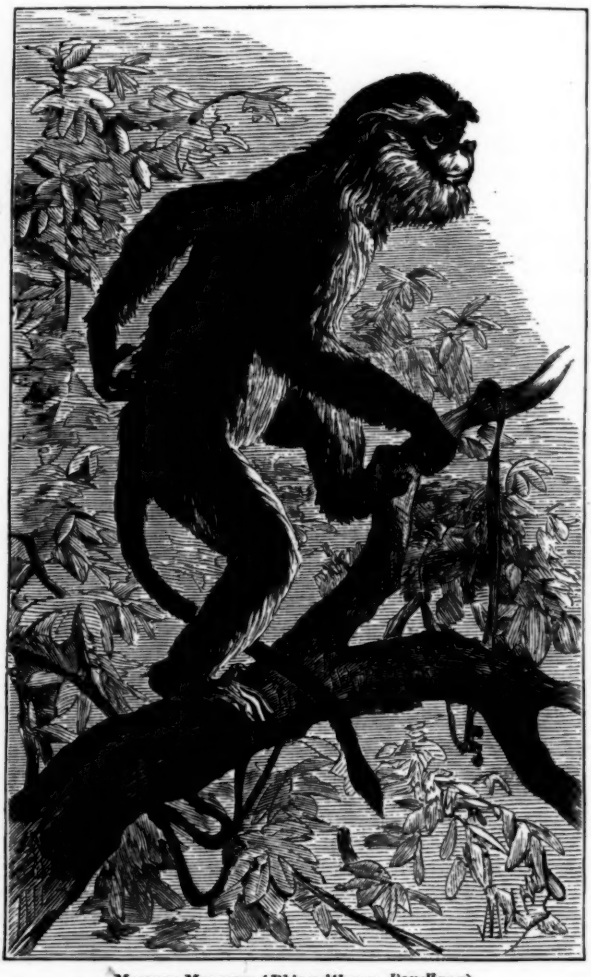
[1] The effect of mixing varieties requires careful investigation, for it is yet very imperfectly understood. There seems little doubt, however, that there is a limit beyond which varieties do not mix with improvement.

MONKEYS FROM A COLD CLIMATE.

TRANSLATED FROM THE FRENCH BY J. FITZGERALD, A. M.

FOR upward of ten years, the Abbé Armand David, a Catholic missionary, has devoted himself to studying the fauna and flora of regions in the Chinese Empire previously unvisited by any European naturalist. He has enriched the Paris Museum of Natural History with collections of great value, representing a number of species either new to science, or not known to have their habitat in Eastern Asia. The Abbé David came to Peking in July, 1862, and in the following year made his first remittance to the museum, of natural history specimens collected and prepared by himself. In 1864 he spent several months at a point 125 miles north of Peking, collecting there fresh materials. Two years later he was in Mongolia, where he spent several months. In 1868 he explored the province of Kiangsi, in Central China, discovering several new species. Toward the end of that year he ascended the Yang-tse-kiang, on a steamer, as far as the city of Hanyang. Thence he made the voyage to the ancient city of Ichang, on a junk, navigating a series of lakes and canals. After a week of difficult navigation he again reached the Yang-tse-kiang, and embarked on a junk of greater tonnage for the province of Szchuen; but, landing at Chungking, he left his baggage on board the junk, and himself cut across-country, reaching Chingtu, the capital of Szchuen, after twelve days' travel. Here M. David spent two months, hunting and botanizing in the surrounding country. Toward the end of February, 1869, he was on the road again, traveling westward over a rugged country, till he reached the border of Moupin, an independent principality, situated on the frontier of China proper. Most maps of Eastern Asia make no mention of Moupin, which is inhabited by the Mantzes, a race differing from both the Chinese and the Tibetans, though they resemble the latter rather than the former. This country lies between Kokonor, the K'ham country, and H'lassa, and is separated from Nepaul, Bhotan, and Assam, by the main range of the Himalaya. But the country really forms a part of the Himalaya region, being covered with lofty mountains whose summits are clad with perpetual snow. Hence, though the centre of Moupin is situated between the thirty-first and the thirty-second degree of north latitude, that is to say, in the latitude of Egypt, its winters are extremely cold, the snow persists in the valleys for several months, and, during the rest of the year, the rain and snow fall with great frequency. This constant humidity of the atmosphere gives rise to a very abundant vegetation; on all sides are to be seen magnolias, laurels, and rhododendrons, which often attain a considerable size; and the mountains

are covered half-way up their sides with forests of pine and cedar. In this country, altogether unknown to Europeans, M. David took up his abode, in the midst of a great valley, situated 2,129 metres (about 7,000 feet) above the sea-level, and only one day's journey from Hong-chan-tin, a mountain over 5,000 metres (nearly 16,500 feet) in height, but commanded by still loftier snow-clad peaks on the north and the southwest.



MOUPIN MONKEY (*Rhinopithecus Roxellanæ*).

No sooner had he reached this locality than there arose difficulties apparently insurmountable. A decree had a little before been issued prohibiting the destruction of game of any kind, in view of a new incarnation of the Buddha. But fortunately the native hunters listened to reason, and M. David succeeded in quieting their scruples by means

of money. In this way he secured a number of birds and mammals, of species that one would not have expected to find in that country.

Among the interesting types discovered in Moupin, we must assign the preëminence to a monkey with long hair and *retroussé* nose, which Alphonse Milne-Edwards has described and figured under the name of *Rhinopithecus Roxellanæ*. This species inhabits the mountains in the western portion of Moupin, as also the district of Yaotchy, and as far as Kokonor. Thus it lives in a region where snow remains on the ground during more than six months in the year. According to the hunters, these monkeys are found in the woods, and always in large troops. Usually, they remain on the tops of lofty trees, and feed on the fruit and young shoots of the wild-bamboo. In possessing no cheek-pouches for stowing away food, and in having one tubercle only on the last molar tooth of the lower jaw, they resemble the *Semnopitheci;* but yet they cannot be classed in the same genus, since, both in anatomical structure and in external aspect, the Moupin monkey presents certain peculiarities which entitle it to a special position among simians. Thus, in the *Semnopitheci*, for instance in the simpai, the entellus, and the budeng, or negro-monkey, the limbs are disproportionately long as compared with the body; the thumb of the anterior hands is short and situated very far back; the tail is long and slender; while in the Moupin monkey the limbs are short and very muscular, the body very strongly built, the tail tufted and shorter in proportion than in the entellus. Besides these, there exist several other characteristics which fully justify the making of a new genus for this Moupin monkey. Thus, the anterior and posterior limbs present no considerable disproportion, as is the case with many of the *Semnopitheci;* the upper arm-bone is very long, longer than the forearm, and its circumference is much increased in its articular portion; the radius (one of the bones of the forearm) presents a strong curvature, with its convexity turned forward, the result being that the interosseous space acquires an exceptionally large size; the hand is large and thick, instead of being long and slender, as in the simpai; but the thumb is quite as rudimentary as in the latter species, and its terminal joint barely extends below the extremity of the first metacarpal bone. The bones of the rest of the fingers are very much bent, which enable the hand to grasp a branch very firmly. The thigh-bone is stout and longer than the large bone of the leg. Finally, the finger-bones of the posterior hands (feet) are short and bowed, which circumstance gives to the palm the form of an arch, and the thumb, instead of being almost atrophied, as in the anterior hands, reaches to the extremity of the first phalange of the index-finger.

The conformation of the head indicates an animal of higher intelligence than the macaques and the *Semnopitheci*. Thus the face is but weakly prognathous; or, in other words, the lower jaw, compared

with the forehead, does not offer that bold prominence which is nearly always a token of ferocity. The brain-case is large and well developed posteriorly, and the temporal ridge, i. e., the bony prominence to which are attached the principal muscles of the under jaw, is smaller than in the *Semnopitheci*. The eye-sockets are round, the cheek-bones prominent, and the nasal region, instead of being in a right line with the forehead, as in the mitred monkey and the great monkey of Cochin-China, is deeply depressed, giving to the face a very peculiar expression. The bones of the nose are reduced to an extreme degree, and the openings of the nostrils, especially in the adult, are very large.

The teeth are remarkable for their development, and in the male the canines are long and sharp.

Alphonse Milne-Edwards has published, in his work on the "Natural History of the Mammalia," a detailed description of this monkey, accompanied by a colored plate, from which our engraving is copied. Unfortunately, the engraving cannot give any idea of the coloration of the animal, and hence we must briefly describe it in words.

The Moupin monkey is of considerable size, the adult male measuring one metre and forty centimetres from the extremity of the muzzle to the extremity of the tail. The face is short, turquoise-green in color; the eyes are large, with nut-brown iris; the nose is turned up at the point. It is to this latter peculiarity, which becomes all the more striking as the animal grows older, that the Moupin monkey is indebted for its generic name *Rhinopithecus*.

The skin around the eyes is greenish, and the nose and muzzle almost naked. But the cheek-bones, the jaws, and the superciliary arches, are covered with thick hair. On the forehead, this hair, which is of a bright reddish-yellow color, is mixed with darker hairs tipped with black. The upper part of the head is covered with grayish-black hair, mixed with rust-color; it forms a sort of skull-cap, and is directed toward the back of the head.

The nape of the neck and the shoulders are of the same color as the crown of the head, but the back, and especially the posterior portion of the trunk, is of a more lively and brilliant hue, owing to the presence of numerous yellowish-gray hairs, with reflex of silver. In old individuals the hairs attain the length of ten centimetres (nearly four inches). On the outside of the arms similar hairs are to be seen, though of duller hue, and on the front of the thighs and legs there is a stripe of iron-gray. But the hinder and outside aspect of the thighs is of a very light yellow, and the inner surfaces of the thighs and legs rust-colored, changing to reddish on the upper side of the feet.

The hair of the anterior hands is gray. The tail is thick and tufted, dark gray at the root and whity gray at the tip.

The female is distinguished from the male by certain differences

of coloration. In the former the side of the neck is gray rather than yellowish, and the tail is of a dull and uniform color. In the young monkeys the skull-cap is small, and the sides of the face are ornamented with a sort of whiskers, which disappear in the adult.

The natives give to the species the name of Kin-tsin-heou, i. e., Brown-and-gold monkey. They hunt it for the sake of its skin, which they use as a preventive against rheumatism.

In the same region with the *Rhinopithecus* there live in small troops, on the most inaccessible wooded declivities, other monkeys who display extreme agility, and who hide in caves, like the Magots or apes of Algeria or Gibraltar. These monkeys, it appears, were once very common here, one old hunter having boasted, in the hearing of M. David, of having killed seven or eight hundred of them in one year. Now, however, they are met with but seldom. With their very short tail and the long hair covering their bodies, they resemble the Magot, properly so called, but they are heavy-built, and the face is longer. One individual, sent to the museum by the Abbé David, is eighty centimetres (2 ft. 7½ in.) in length; his head is very large compared to his body; the face is bare and flesh-colored, darker and mottled around the eyes, and brownish about the mouth. Tufted whiskers of a bright gray adorn the sides of the head, and the forehead and the crown of the head are covered with short hairs, of a dull-brown color. The hair of the nape of the neck and of the shoulders is nearly as long as that of the Moupin monkey, and dark in color. The breast and belly are grayish. The anterior hands are small, while the posterior hands are well developed and heavily covered with hair on the upper surface. The tail is rudimentary, and the callosities well marked.

The female is smaller than the male; her skin is of a more uniform color, and softer, and her whiskers are not at all so long.

This species, called by Alphonse Milne-Edwards *Macacus Thibetanus*, would seem to be far more brutish than the preceding, for in the male the bony ridges of the skull are very prominent, and resemble those seen in the head of the gorilla.

In a species from Cochin-China, discovered by David, and described by Isidore Geoffrey St.-Hilaire, under the name of *Macaque oursin*, the cranium presents similar ridges, but far less developed. From the information gathered by M. David, it would appear that there exist in Eastern Tibet at least two other species of large, long-tailed monkeys; of these, the one is said to be of a greenish-yellow color, and the other of a deep black.—*La Nature.*

PHYSICAL FEATURES OF THE COLORADO VALLEY.[1]

By Major J. W. POWELL.

III. *Water-Sculpture.*

THE more important topographic features in the valley of the Colorado are mountains, hills, hog-backs, bad-lands, alcove-lands, cliffs, buttes, and cañons. The primary agency in the production of these features is upheaval, i. e., upheaval in relation to the level of the sea, though it may possibly be down-throw in relation to the centre of the earth. This movement in portions of the crust of the earth may be by great folds, with anticlinal or synclinal axes, and by monoclinal folds and faults.

The second great agency is erosion, and the action of this agency is conditioned on the character of the displacements above mentioned, the texture and constitution of the rocks, and the amount and relative distribution of the rains.

In a district of country, the different portions of which lie at different altitudes above the sea, the higher the region the greater the amount of rainfall, and hence the eroding agency increases in some well-observed but not accurately-defined ratio, from the low to the high lands. The power of running water, in corrading channels and transporting the products of erosion, increases with the velocity of the stream in geometric ratio, and hence the degradation of the rocks increases with the inclination of the slopes. Thus altitude and inclination both are important elements in the problem.

Let me state this in another way. We may consider the level of the sea to be a grand base-level, below which the dry lands cannot be eroded; but we may also have, for local and temporary purposes, other base levels of erosion, which are the levels of the beds of the principal streams which carry away the products of erosion. (I take some liberty in using the term level in this connection, as the action of a running stream in wearing its channel ceases, for all practical purposes, before its bed has quite reached the level of the lower end of the stream. What I have called the base-level would, in fact, be an imaginary surface, inclining slightly in all its parts toward the lower end of the principal stream draining the area through which the level is supposed to extend, or having the inclination of its parts varied in direction as determined by tributary streams.) Where such a stream crosses a series of rocks in its course, some of which are hard, and others soft, the harder beds form a series of temporary dams, above which the corrasion of the channel through the softer beds is checked,

[1] From "Report on United States Geological and Geographical Survey of the Territories, Second Division," J. W. Powell in charge.

and thus we may have a series of base-levels of erosion, below which the rocks on either side of the river, though exceedingly friable, cannot be degraded. In these districts of country, the first work of rains and rivers is to cut channels, and divide the country into hills, and perhaps mountains, by many meandering grooves or water-courses, and when these have reached their local base-levels, under the existing conditions, the hills are washed down, but not carried entirely away.

With this explanation I may combine the statements concerning elevation and inclination into this single expression, that the more elevated any district of country is, above its base-level of denudation, the more rapidly it is degraded by rains and rivers.

The second condition in the progress of erosion is the character of the beds to be eroded. Softer beds are acted upon more rapidly than the harder. The districts which are composed of softer rocks are rapidly excavated, so as to become valleys or plains, while the districts composed of harder rocks remain longer as hills and mountains.

Where the beds are of stratified material, so that the change from harder to softer materials is from bed to bed, rather than from district to district, and in a vertical or inclined direction, rather than an horizontal, the topographic features, which I have described as hog-backs and cliffs of erosion, are produced. The difference between hog-backs and cliffs of erosion is chiefly due to the amount of dip or inclination of the beds.

But there is another condition necessary to the production of cliffs and hog-backs in their typical forms. The country must be arid, for, where there is a great amount of rainfall, the water penetrates and permeates the rocks, and breaks them up, or rots them, to use an expression which has been employed with this meaning; and the difference between the durability of the harder beds and that of the softer is, to some extent, compensated for by this agency, though doubtless ridges and cliffs may be produced in less arid climates, as we find them in the Appalachian System, but not so well marked. In a region of country where there is a greater amount of rainfall, the tendency is to produce hills and mountains, rather than plateaus and ridges, with escarpments.

Now let us examine the character of the channels which running streams carve. Where the rocks to be carved are approximately horizontal, and composed of stratified beds of varying thickness, the tendency is to cut channels with escarpments or cliffs; but if the beds are greatly inclined, or composed of unstratified material, the tendency is to cut channels with more flaring and irregular walls. These tendencies are more clearly defined when the meteorologic conditions are favorable—that is, if a stream cuts through stratified rocks, in an arid region, and carries the waters from a district more plentifully supplied, the cliff character of the walls is increased; and where a

stream runs through unstratified rocks, in a district well supplied with rains, the walls or banks of the stream are cut down in more gentle slopes.

For purposes of discussion, it will be convenient to call the deep

SECTION OF WALL IN THE GRAND CAÑON.

channels of streams through table-lands, in arid climates, cañons; and the deep channels of streams through heterogeneous beds, in a moist climate, water-gaps, or narrows, and ravines.

Having in view the forms which are produced by erosion, it will be convenient to classify the methods of erosion as follows: First, corrasion by running streams, and, second, erosion by rains; the first producing channels along well-defined lines, the second producing the general surface features of the landscape.

Of the first class we have two varieties:

A. The corrasion of water-gaps.

B. The corrasion of cañons.

Of the second class we have three varieties:

A. Cliff erosion, where the beds are slightly inclined, and are of heterogeneous structure, some soft and others hard; and, for the production of the best-marked forms, the climate should be arid. Here the progress of erosion is chiefly by undermining.

B. Hog-back erosion, where the beds have a greater inclination, but are still of heterogeneous structure. Here the progress of erosion is by undermining and surface-washing, and the typical forms would require an arid climate.

C. Hill and mountain erosion, where the beds may lie in any shape, and be composed of any material not included in the other classes, and the progress of erosion is chiefly by surface-washing. The typical forms are found in a moist climate.

There is still another agency in the production of topographic features, viz., the eruption of molten matter from below the general surface. The beds formed are soon modified by erosion, and then the forms produced are due to that agency, and fall under the general series. But there is a time, immediately after the eruption, when these beds lie in forms due to igneous dynamics, and the most important features produced are cones. These cones are very conspicuous features of the landscape over much of the region drained by the Colorado River.

The district of country drained by the Colorado and its tributaries is divided into two parts, by a well-marked line of displacements. The lower third of the valley, which lies southward from this line, is but little above the level of the sea, except that here and there ranges of mountains are found. From this region, there is usually a bold step to a higher.

The upper two-thirds of the area drained by the Colorado is from 4,000 to 8,000 feet above the level of the sea, with mountain-ranges on the east, north, and west, of greater altitude. The bold step from the lower country to the table-lands is usually an escarpment in rocks of the Carboniferous Age, marked, here and there, by beds of lava, and along its margin stand many volcanic cones. San Francisco Mountain is made up of a group of these beds of eruptive matter, covering stratified rocks. This higher region is the one to which we have given especial attention in the previous discussion.

The principal condensation of moisture occurs on and about the

mountains standing on the rim of the basin, the region within being arid.

Bad-lands, alcove-lands, plains of naked rock, plains of drifting sands, *mesas*, plateaus, buttes, hog-backs, cliffs, volcanic cones, volcanic mountains, cañons, cañon valleys, and valleys, are all found in this region, and make up its topographic features. Mountains, hills, and small elevated valleys, are the features of the irregular boundary belt.

No valley is found along the course of the Colorado, from the Grand Wash toward the sources of the river, until we reach the head of Labyrinth Cañon. For this entire distance the base-level of erosion is below the general surface-level of the country adjacent to the river, but at Gunnison's Valley we have a local base-level of erosion which has resulted in the production of low plains and hills for a number of miles back from the stream. North of the Cañon of Desolation and south of the Uinta Mountains, another local base-level of erosion is found, so near to the general surface of the country that we find a district of valleys and low hills stretching back from Green River, up the Uinta to the west, and White River to the east, for many miles. North of the Uinta Mountains a third local base-level of erosion is seen, but its influence on the topographic features is confined to a small area of 200 or 300 square miles. Going up the chief lateral streams of the Colorado, we find one or more of these local base-levels of erosion, where the streams course through valleys.

Where these local base-levels of erosion exist, forming valley and hill regions, the streams no longer cut their channels deeper, and the waters of the streams, running at a low angle, course slowly along, and are not able to carry away the products of surface-wash, and these are deposited along the flood-plains, in part, and in the valleys, among hills, and on the gentler slopes. This results in a redistribution of the material in irregular beds and aggregations.

In this region, there are occasional local storms of great violence. Such storms may occur in any particular district only at intervals of many years, possibly centuries. When such a one does occur, it reopens great numbers of channels that have been filled by the ordinary wash of rains, and often cuts a new channel through beds which have accumulated in the manner above described. The structure of these beds is well exposed, and we find beds of clay, beds of sand, and beds of gravel occurring in a very irregular way, due to the vicissitudes of local wash, and, where the progress of erosion has been more or less by undermining, larger fragments or bowlders are found, and these bowlders are sometimes mixed with clay, and sometimes with sand and gravel, and where thin sheets of eruptive rocks have been torn to pieces, more or less by undermining (for such is the usual way in this country), the beds appear to contain erratics, and in fact some of the rocks are erratics, for in the various changes in the levels produced

they have often been transported many miles, not by sudden and rapid excursions, but moved a little from time to time.

Again, the beds from which they were derived, doubtless, in many cases have been broken up or lost, and these fragments only remain to attest the existence of such beds in some former time, and all stages may be observed, from the beds the edges only of which have been broken up, to those that have only fragments remaining or have entirely disappeared. Another interesting fact has been observed, that these erratics or bowlders are often found distributed somewhat in lines due to the undermining of lines of cliffs. Often where we have cliffs capped with a bed of lava, former and more advanced positions of these lines of cliffs can be recognized by the position of lines of lava-fragments which are seen in the valley or plains in front of the cliffs. It will be seen that these local accumulations of material, due to the excess of erosion over that of transportation, greatly resemble the accumulations of "the Drift." Especially is this true where I have studied the latter in the valley of the Mississippi, and I have been led to query whether it may not be possible to refer the origin of the Drift of the valley of the Mississippi, in part at least, to some such action as this; not that I question the evidence of extended glacial action in that region, but may it not be that this glacial action has only resulted in somewhat modifying a vast accumulation of irregularly-bedded material, originally due to the fact that the grand base-level of erosion had been reached by the running streams of that region, and hills and mountains had been degraded by having the material of which they were composed scattered over lower lands, without being carried away by streams to the sea?

All the mountain-forms of this region are due to erosion; all the cañons, channels of living rivers and intermittent streams, were carved by the running waters, and they represent an amount of corrasion difficult to comprehend. But the carving of the cañons and mountains is insignificant, when compared with the denudation of the whole area, as evidenced in the cliffs of erosion. Beds hundreds of feet in thickness and hundreds of thousands of square miles in extent, beds of granite and beds of schist, beds of marble and beds of sandstone, crumbling shales and adamantine lavas, have slowly yielded to the silent and unseen powers of the air, and crumbled into dust and been washed away by the rains and carried into the sea by the rivers.

The story we have told is a history of the war of the elements to beat back the march of the lands from ocean-depths.

And yet the conditions necessary to great erosion in the valley of the Colorado are not found to exceed those of many other regions. In fact, the aridity of the climate is such that this may be considered a region of lesser, rather than greater, erosion. We may suppose that, had this country been favored with an amount of rainfall similar to that of the Appalachian country, and many other districts on

the surface of the earth, the base-level of erosion of the entire area would have been the level of the sea; and, under such circumstances, though the erosion would have been much greater than we now find, the evidences of erosion would have been more or less obliterated. As it is, we are able to study erosion in this country, and find evidences of its progress and its great magnitude, from the very fact that the conditions of erosion have been imperfect.

It is proper to remark here that erosion does not increase in ratio to the increase of the precipitation of moisture, as might be supposed; for, with the increase of rains there will be an increase of vegetation, which serves as a protection to the rocks, and distributes erosion more evenly, and it may be that a great increase of rains in this region would only produce a different series of topographic outlines, without greatly increasing the general degradation of the valley of the Colorado.

To a more thorough discussion of this subject I hope to return at some future time.

From the considerations heretofore presented, it is not thought necessary to refer the exhibition of erosion shown in the cañons and cliffs to a more vigorous action of aqueous dynamics than now exists, for, as I have stated, a greater precipitation of moisture would have resulted in a very different class of topographic features. Instead of cañons, we should have had water-gaps and ravines; instead of valleys with cliff-like walls, we should have had valleys bounded by hills and slopes; and if the conclusions to which we have arrived are true, the arid conditions now existing must have extended back for a period of time of sufficient length to produce the present cañons and cliffs. But there are facts which seem to warrant the conclusion that this condition has existed for a much longer period than that necessary for the production of the present features; that is, the characteristics of the present topography have existed for a long time. There are evidences that the lines of cliffs themselves have been carried back for great distances as cliffs by undermining, which is a process carried on only in an arid region.

The evidence is of this character: I have stated that the drainage of the inclined plateaus is usually from the brink of the cliffs backward; i. e., the water falling on the plateau does not find its way immediately over the cliffs, but runs from the very brink or edge of the plateau back toward the middle or farther side, which is usually found against the foot of another line of cliffs, and here the waters are turned toward some greater channel, which runs against the dip and cuts through the cliffs. Now, the water-ways at the heads of these streams that have their sources near the brink of the cliffs would always be small, shallow, and ramifying into many minute branches if the line of cliffs were a fixed or immovable line, but we often find that the cliffs have been carried back by the undermining process until all

these minute ramifications have been cut off; and we find cañons opening on the faces of the cliffs, the waters of which run backward as above described.

Let us suppose that we have a line of cliffs with an escarpment facing the south. The rain, falling on the escarpment and in the region south of the cliffs, would run toward the south or along the foot of the cliffs until it reached some more important water-channel; the rain falling on the plateau, from the brink of the cliffs backward, would run toward the north, and the waters falling on this upper region would excavate channels for themselves, and, under proper conditions, cañons would be cut. As the cliffs are undermined and this line carried back into the plateau, the area with a southern drainage would be increased, the area with a northern drainage correspondingly diminished, and, when the process had continued for a sufficient length of time, we would find the southern edge of the plateau carried away by this undermining process, until all the heads of the streams were cut off and until the line had reached the cañons.

Gradually, during the progress of erosion, the excavation of the bottom of the cañons would cease, as the supply of water running through them would be cut off, and such cañons would have to be considered as comparatively ancient. Such facts are frequently observed in this cañon and cliff country.

From such considerations, it seems that we may safely conclude that the cliff topography has prevailed in that region for a long time. There are evidences also that there were cañons here before the present cañons were carved. The facts in relation to this matter can be better stated when we come to discuss the geology of the region.

Mr. G. K. Gilbert, a geologist of Lieutenant Wheeler's corps, in a paper communicated to the Philosophical Society of Washington, in 1873, deduced a similar conclusion from an independent series of facts observed in Western Utah. The basin of Great Salt Lake, a portion of what Fremont designated the "Great Basin," has now so dry a climate that its waters gather in its lowest parts and evaporate, and have no outlet to the sea. In a former period, however, there was more rain, the valley was filled with water to its brim, and in place of the Salt Lake Desert, there was a broad and deep fresh lake, discharging its surplus into the Columbia River. The epoch of this lake Mr. Gilbert finds reason to consider identical with the Glacial Epoch, and it was of limited duration. Among its vestiges are deposits of fossiliferous marl, which are conspicuously contrasted with the gravels and sand that now slowly accumulate in the same region, borne by the intermittent streams that descend from the mountains. Where the beds are superposed, the marls testify to a moist climate and the gravels to a climate so dry that the basin was never filled with water. But above the marls are found only scattered and thin deposits of gravel, while below them the gravel-beds are omnipresent and of

great depth, and hence it was reasoned that the arid period that preceded the Glacial Epoch was many times longer than that which has followed it.

Even during the Glacial Epoch, Mr. Gilbert considers that "the Atlantic slope, and the region of the Great Basin, were contrasted in climate, just as now. The general causes that covered the humid East with a mantle of ice, sufficed, in the arid West, only to flood the valleys with fresh water, and send a few ice-streams down the highest mountain-gorges." [1]

Records of More Ancient Lands.—The summit of the Kaibab Plateau is more than 6,000 feet above the river, and I have already mentioned that the summit of the plateau is also the summit of rocks of the Carboniferous Age. These beds are about 3,500 feet in thickness, and beneath them we have 1,000 feet of conformable rocks of undetermined age. This gives us 4,500 feet, from the summit of the plateau down to the non-conformable beds. Still beneath these we have 1,500 feet, so that we have more than 1,500 feet of other rocks exposed in the depths of the Grand Cañon. Standing on some rock, which has fallen from the wall into the river—a rock so large that its top lies above the water—and looking overhead, we see a thousand feet of crystalline schists, with dikes of greenstone, and dikes and beds of granite. Heretofore we have given the general name granite to this group of rocks; still, above them we can see beds of hard, vitreous sandstone of many colors, but chiefly dark red. This group of rocks adds but little more than 500 feet to the height of the walls, and yet the beds are 10,000 feet in thickness. How can this be? The beds themselves are non-conformable with the overlying Carboniferous rocks; that is, the Carboniferous rocks are spread over their upturned edges.

In the figure (p. 672) we have a section of the rocks of the Grand Cañon. *A*, *A*, represents the granite; *a*, *a*, dikes and eruptive beds; *B*, *B*, these non-conformable rocks. It will be seen that the beds incline to the right. The horizontal beds above, *C*, *C*, are rocks of Carboniferous Age, with underlying conformable beds. The distance along the wall marked by the line *x*, *y*, is the only part of its height represented by these rocks, but the beds are inclined, and their thickness must be measured by determining the thickness of each bed. This is done by measuring the several beds along lines normal to the planes of stratification; and, in this manner, we find them to be 10,000 feet in thickness.

Doubtless, at some time before the Carboniferous rocks *C*, *C*, were formed, the beds *B*, *B*, extended off to the left, but between the periods of deposition of the two series, *B*, *B*, and *C*, *C*, there was a period of erosion. The beds themselves are records of the invasion

[1] Bulletin of the Philosophical Society, Washington, forty-sixth meeting, April 26, 1873.

of the sea; the line of separation, the record of a long time when the region was dry land. The events in the history of this intervening time, the period of dry land, one might suppose were all lost. What plants lived here, we cannot learn; what animals roamed over the hills, we know not; and yet there is a history which is not lost, for we find that after these beds were formed as sediments beneath the sea, and still after they had been folded, and the sea had left them, and the rains had fallen on the country long enough to carry out 10,000 feet of rocks, the extension of these beds to the south, which were cut away, and yet before the overlying Carboniferous rocks were formed as sediments of sand and triturated coral-reefs, and ground shells and pulverized bones, some interesting events occurred, the records of which are well preserved. This region of country was fissured, and the rocks displaced so as to form faults, and through the fissures floods of lava were poured, which, on cooling, formed beds of trap or greenstone. This greenstone was doubtless poured out on the dry land, for it bears evidence of being eroded by rains and streams prior to the deposition of the overlying rocks.

Let us go down again, and examine the junction between these red rocks, with their intrusive dikes and overlying beds of greenstone, and the crystalline schists below.

We find these lower rocks to be composed chiefly of metamorphosed sandstones and shales, which have been folded so many times, squeezed, and heated, that their original structure, as sandstones and shales, is greatly obscured, or entirely destroyed, so that they are called metamorphic crystalline schists.

Dame Nature kneaded this batch of dough very thoroughly. After these beds were deposited, after they were folded, and still after they were deeply eroded, they were fractured, and through the fissures came floods of molten granite, which now stands in dikes, or lies in beds, and the metamorphosed sandstones and shales, and the beds of granite, present evidences of erosion subsequent to the periods just mentioned, yet antecedent to the deposition of the non-conformable sandstones.

Here, then, we have evidences of another and more ancient period of erosion, or dry land. Three times has this great region been left high and dry by the ever-shifting sea; three times have the rocks been fractured and faulted; three times have floods of lava been poured up through the crevices; and three times have the clouds gathered over the rocks, and carved out valleys with their storms. The first time was after the deposition of the schists; the second was after the deposition of the red sandstones; the third time is the present time. The plateaus and mountains of the first and second periods have been destroyed or buried; their eventful history is lost; the rivers that ran into the sea are dead, and their waters are now rolling as tides, or coursing in other channels. Were there cañons then? I

think not. The conditions necessary to the formation of cañons are exceptional in the world's history.

We have looked back unnumbered centuries into the past, and seen the time when the schists in the depths of the Grand Cañon were first formed as sedimentary beds beneath the sea; we have seen this long period followed by another of dry land—so long that even hundreds, or perhaps thousands, of feet of beds were washed away by the rains; and, in turn, followed by another period of ocean triumph, so long, that at least 10,000 feet of sandstones were accumulated as sediments, when the sea yielded dominion to the powers of the air, and the region was again dry land. But aërial forces carried away the 10,000 feet of rocks, by a process slow yet unrelenting, until the sea again rolled over the land, and more than 10,000 feet of rocky beds were built over the bottom of the sea; and then again the restless sea retired, and the golden, purple, and black hosts of heaven made missiles of their own misty bodies—balls of hail, flakes of snow, and drops of rain—and when the storm of war came, the new rocks fled to the sea. Now we have cañon-gorges and deeply-eroded valleys, and still the hills are disappearing, the mountains themselves are wasting away, the plateaus are dissolving, and the geologist, in the light of the past history of the earth, makes prophecy of a time when this desolate land of Titanic rocks shall become a valley of many valleys, and yet again the sea will invade the land, and the coral animals build their reefs in the infinitesimal laboratories of life, and lowly beings shall weave nacre-lined shrouds for themselves, and the shrouds shall remain entombed in the bottom of the sea, when the people shall be changed, by the chemistry of life, into new forms; monsters of the deep shall live and die, and their bones be buried in the coral sands. Then other mountains and other hills shall be washed into the Colorado Sea, and coral-reefs, and shales, and bones, and disintegrated mountains, shall be made into beds of rock, for a new land, where new rivers shall flow.

Thus ever the land and sea are changing; old lands are buried, and new lands are born, and with advancing periods new complexities of rock are found; new complexities of life evolved.

A NEW ANTISEPTIC.

CHEMISTS have long been familiar with the substance known as salicylic acid, and in the text-books most of its properties are described, as also the various modes of preparing it. Its most valuable property, however, namely, its action as an anti-ferment and antiseptic, was discovered only about a year ago, by Prof. Kolbe, of the

University of Leipsic. Salicylic acid exists ready-formed in the flowers of *Spiræa ulmaria* (meadow-sweet), and as methyl-salicylic acid in oil of wintergreen. It is also prepared from indigo and from *salicin*, a substance found in the bark of several species of willow and poplar. But the best mode of preparing it is that proposed by Kolbe and Lautemann, which is thus described by Watts:

Dry carbonic anhydride is passed into warm phenol, with addition of small pieces of sodium. The metal then dissolves, with evolution of hydrogen, and a stiff paste is formed, containing the isomeric salts, salicylate and phenyl-carbonate of sodium, together with unaltered phenol. On acidulating with hydrochloric acid, the phenyl-carbonic acid is decomposed, with evolution of carbonic anhydride, and the salicylic acid which is set free may be separated from the phenol by solution in strong aqueous carbonate of ammonium. The solution, boiled down till it acquires a slight acid reaction, filtered from separated resin, and mixed with hydrochloric acid, yields salicylic acid, to be purified by recrystallization with the aid of animal charcoal.

Reasoning from the fact that salicylic acid can thus be prepared from phenol and carbonic acid, and from the further fact that on the application of heat it again splits up into those two acids, Kolbe was led to inquire whether it possessed the antiseptic properties of phenol. The value of the latter substance as an anti-ferment is well known, but its poisonous properties, as well as its disagreeable smell and acrid taste, render it unsuitable as a means of preserving articles of food, or as a medicinal agent. It was evident, therefore, that if salicylic acid, which is odorless, almost tasteless, and, when taken in small quantities, innocuous, possessed antiseptic properties equal to those of phenol, one of the most urgent wants of modern life would be at once supplied. Experiment proved the conjecture to be correct, and thus many years of theoretical investigation were crowned by practical results of the highest value.

Among the experiments made with this substance we may mention the following: Brewer's yeast (quantity not stated), which causes alcoholic fermentation of sugar, was found to have no effect upon a solution of glucose containing the one-thousandth part of salicylic acid. Half a gramme of the acid suffices to check the fermentation produced by five grammes of beer-yeast, acting on 120 grammes of sugar dissolved in a litre of water. Experiments made by Neubauer show that 100 grammes of salicylic acid suffices to absolutely prevent fermentation in 1,000 litres of *must*, or fresh-pressed juice of grapes. Flour of mustard, which, when mixed with lukewarm water, gives out the pungent oil of mustard, is perfectly odorless when a small quantity of salicylic acid is added to it. So, too, this acid prevents the action of emulsin (the ferment contained in almonds) upon amygdalin, and the conversion of the latter into oil of bitter-almonds. Milk treated with 0.04 per cent. of salicylic acid remained uncoagulated for thirty-six

hours longer than milk not so treated. In like manner a litre of beer, containing one gramme of the acid, and exposed to the air, did not become sour after standing for a considerable time, nor was there the slightest trace of mould. As a means of keeping water sweet on shipboard it is specially valuable.

Eggs immersed for an hour in a solution of salicylic acid were at the end of three months as fresh as at first. Flesh-meat dusted over with the acid keeps its freshness for weeks. When about to be used, the meat may be dipped into water, to remove the acid.

Dr. Thiersch, of the Leipsic Hospital, has used this substance "with very favorable results" in his surgical practice. Kolbe has employed it as a wash for the teeth and mouth, and asserts that it is very effectual in purifying the breath. In a communication published in the *Journal für praktische Chemie*, he says: "As a medicine for internal use, salicylic acid does not seem to have been much employed hitherto, and yet, owing to its antiseptic properties, it is indicated in all diseases of the blood, especially in those which are developed by contagion." Among the diseases likely to yield to this treatment he names scarlatina, diphtheria, measles, small-pox, syphilis, dysentery, typhus, and cholera. Further, he is inclined to think that it might be effectual in dealing with pyæmia and hydrophobia.

Dr. Karl Fontheim, writing to the same journal, says: "This new remedy has been found of very special benefit in treating diphtheria; I have employed it in thirty-two cases; of these none have proved fatal, and the worst cases recovered in eight days." Prof. Zürn, of Leipsic, has employed salicylic acid in veterinary practice, both medical and surgical, and it is his opinion that "for internal and external use in domestic animals, as an antiseptic and destroyer of living contagia, it is destined to occupy as honorable a position in veterinary practice as it does in human medicine."

Kolbe has experimented on his own person, to determine whether or not salicylic acid is injurious to the animal economy. For several days in succession he took daily, in four parts, one half-gramme (solution in water 1 : 1,000), without the slightest bad effect. After an interval of eight days, he for five successive days took double the former dose, and for two successive days he took one and a half gramme. In the mean time his digestion was entirely normal; there was no feeling of oppression in the stomach, nor did he experience any inconvenience whatever. Other physicians who, at his request, made the same experiments, confirm these results. Still the remedy must not be taken in the form of a powder, for in that shape it attacks the mucous membrane of the mouth and œsophagus; it must be taken in solution.

F. von Heyden, of Dresden, manufactures salicylic acid on a large scale, according to the process of Kolbe and Lautemann. The product is a yellowish-white powder. This is the crude acid, which may be

employed for disinfecting purposes. When intended for preserving articles of food, or for medical or surgical uses, this crude acid must be purified, and then its color is snowy white. Rautert has succeeded in sublimating it completely in a current of superheated steam, thus readily obtaining it pure. Recrystallization from hot distilled water gives it in the form of slender needles an inch long.

THE MECHANICAL ACTION OF LIGHT.

By WILLIAM CROOKES, F. R. S

SOME experiments illustrating the mechanical action of light, which I have recently exhibited before the Fellows of the Royal Society, having attracted considerable attention, I propose to give here a description of some of the instruments which my researches have enabled me to construct. But, to render the subject more intelligible, it will be necessary to give a brief outline of the researches which I have been carrying on for the last three or four years, so that the reader may see the gradual steps which have led up to the full proof that radiation is a motive power.

The experiments were first suggested by some observations made when weighing heavy pieces of glass apparatus in a chemical balance, inclosed in an iron case from which the air could be exhausted. When the substance weighed was of a temperature higher than that of the surrounding air and the weights, there appeared to be a variation of the force of gravitation. Experiments were thereupon instituted to render the action more sensible and to eliminate sources of error.[1]

My first experiments were performed with apparatus made on the principle of the balance. An exceedingly fine and light arm was delicately suspended in a glass tube by a double-pointed needle; and at the ends were affixed balls of various materials. Among the substances thus experimented on I may mention pith, glass, charcoal, wood, ivory, cork, selenium, platinum, silver, aluminium, magnesium, and various other metals.

The most delicate apparatus for general experiment was made with a straw beam having pith masses at the end. The general appearance of the apparatus is shown in Fig. 1.

A is the tube belonging to the Sprengel pump.[2] *B* is the desiccator, full of glass beads moistened with sulphuric acid. *C* is the tube containing the straw balance with pith ends: it is drawn out to a con-

[1] "On the Atomic Weight of Thallium," "Philosophical Transactions," 1873, vol. clxiii., p. 287.

[2] For a full description of this pump, with diagrams, *see* "Philosophical Transactions," 1873, vol. clxiii., p. 295.

tracted neck at the end connected with the pump, so as to readily admit of being sealed off at any stage of the exhaustion. *D* is the pump-gauge, and *E* is the barometer.

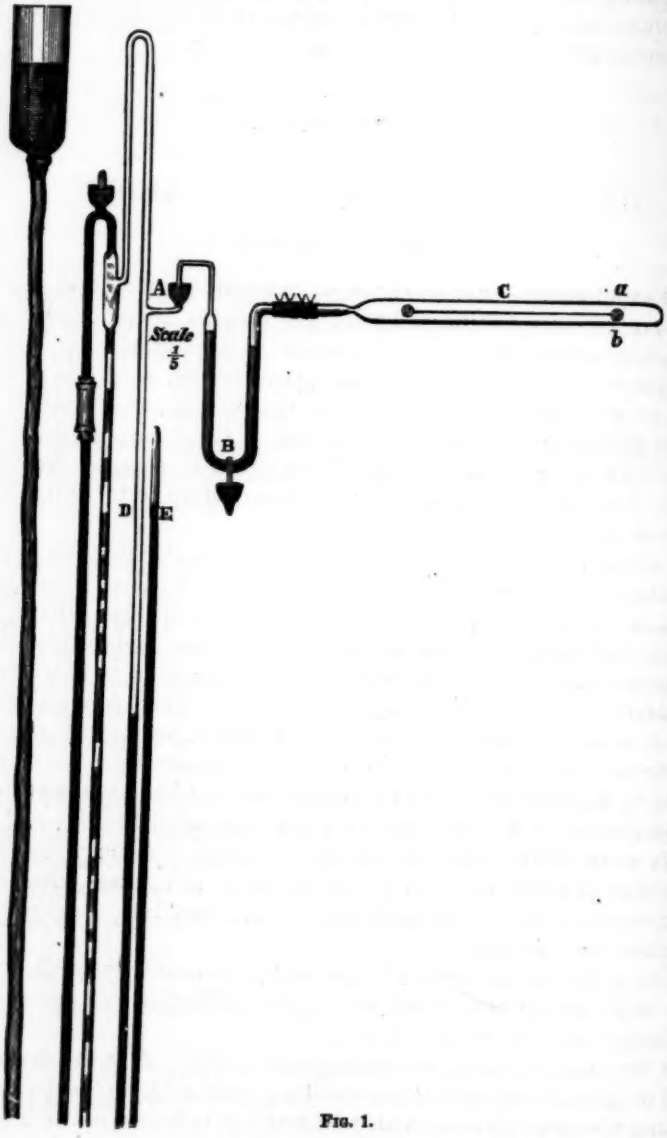


FIG. 1.

The whole being fitted up as here shown, and the apparatus being full of air to begin with, I passed a spirit-flame across the lower part of the tube at *b*, observing the movement by a low-power micrometer: the pith-ball (*a b*) descended slightly, and then immediately rose to

considerably above its original position. It seemed as if the true action of the heat was one of attraction, instantly overcome by ascending currents of air. A hot metal or glass rod and a tube of hot water applied beneath the pith-ball at *b* produced the same effect as the flame; when applied above at *a* they produced a slight rising of the ball. The same effects take place when the hot body is applied to the other end of the balanced beam. In these cases air-currents are sufficient to explain the rising of the ball under the influence of heat.

In order to apply the heat in a more regular manner, a thermometer was inserted in a glass tube, having at its extremity a glass bulb about one and a half inch diameter; it was filled with water and then sealed up (*see* Fig. 2). This was arranged on a revolving stand, so that by means of a cord I could bring it to the desired position without moving the eye from the micrometer. The water was kept heated to 70° C., the temperature of the laboratory being about 15° C.

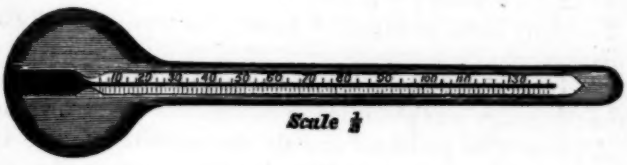


FIG. 2.

The barometer being at 767 millimetres and the gauge at zero, the hot bulb was placed beneath the pith-ball at *b*. The ball rose rapidly. The source of heat was then removed, and as soon as equilibrium was restored I placed the hot-water bulb above the pith-ball at *a*, when it rose again—more slowly, however, than when the heat was applied beneath it.

The pump was then set to work; and when the gauge was 147 millimetres below the barometer, the experiment was tried again: a similar result, only more feeble, was obtained. The exhaustion was continued, stopping the pump from time to time to observe the effect of heat, when it was seen that the effect of the hot body regularly diminished as the rarefaction increased, until, when the gauge was about twelve millimetres below the barometer, the action of the hot body was scarcely noticeable. At ten millimetres below it was still less; while when there was only a difference of seven millimetres between the barometer and the gauge, neither the hot-water bulb, the hot rod, nor the spirit-flame, caused the ball to move in an appreciable degree.

The inference was almost irresistible that the rising of the pith was only due to currents of air, and that at this near approach to a vacuum the residual air was too highly rarefied to have power in its rising to overcome the inertia of the straw beam and the pith-balls. A more

delicate instrument would doubtless show traces of movement at a still nearer approach to a vacuum; but it seemed evident that when the last trace of air had been removed from the tube surrounding the balance—when the balance was suspended in empty space only—the pith-ball would remain motionless, wherever the hot body was applied to it.

I continued exhausting. On next applying heat underneath, the result showed that I was far from having discovered the law governing these phenomena; the pith-ball rose steadily, and without that hesitation which had been observed at lower rarefactions. With the gauge three millimetres below the barometer, the ascension of the pith when a hot body was placed beneath it was equal to what it had been in air of ordinary density; while with the gauge and barometer level its upward movements were not only sharper than they had been in air, but they took place under the influence of far less heat—the finger, for example, instantly repelling the ball to its fullest extent.

To verify these unexpected results, air was gradually let into the apparatus, and observations were taken as the gauge sank. The same effects were produced in inverse order, the point of neutrality being when the gauge was about seven millimetres below a vacuum.

A piece of ice produced exactly the opposite effect to a hot body.

The presence of air having so marked an influence on the action of heat, an apparatus was fitted up in which the source of heat (a platinum spiral rendered incandescent by electricity) was inside the vacuum-tube instead of outside it as before; and the pith-balls of the former apparatus were replaced by brass balls. By careful manipulation and turning the tube round, I could place the equipoised brass ball either over, under, or at the side of the source of heat. With this apparatus I tried many experiments, to ascertain more about the behavior of the balance during the progress of the exhaustion, both below and above the point of no action, and also to ascertain the pressure corresponding with this critical point.

In one experiment, which is described in detail in my paper on this subject before the Royal Society,[1] the pump was worked until the gauge had risen to within five millimetres of the barometric height. On arranging the ball above the spiral, and making contact with the battery, the attraction was still strong, drawing the ball downward a distance of two millimetres. The pump continuing to work, the gauge rose until it was within one millimetre of the barometer. The attraction of the hot spiral for the ball was still evident, drawing it down when placed below it, and up when placed above it. The movement, however, was much less decided than before; and, in spite of previous experience, the inference was very strong that the attraction would gradually diminish until the vacuum was absolute, and that then, and not till then, the neutral point would be reached. Within one milli-

[1] "Philosophical Transactions," 1874, vol. clxiv., p. 501.

metre of a vacuum there appeared to be no room for a change of sign.

The gauge rose until there was only half a millimetre between it and the barometer. The metallic hammering heard when the rarefaction is close upon a vacuum commenced, and the falling mercury only occasionally took down a bubble of air. On turning on the battery-current, there was the faintest possible movement of the brass ball (toward the spiral) in the direction of attraction.

The working of the pump was continued. On next making contact with the battery, no movement could be detected. The red-hot spiral neither attracted nor repelled. I had arrived at the critical point. On looking at the gauge I saw it was level with the barometer.

The pump was now kept at full work for an hour. The gauge did not rise perceptibly, but the metallic hammering sound increased in sharpness, and I could see that a bubble or two of air had been carried down. On igniting the spiral, I saw that the neutral point had been passed. The sign had changed, and the action was one of faint but unmistakable *repulsion*. The pump was still kept going, and an observation was taken, from time to time, during several hours. The repulsion continued to increase. The tubes of the pump were now washed out with oil of vitriol,[1] and the working was continued for an hour.

The action of the incandescent spiral was now found to be energetically *repellent*, whether it was placed above or below the brass ball. The fingers exerted a repellent action, as did also a warm glass rod, a spirit-flame, and a piece of hot copper.

In order to decide once for all whether these actions really were due to air-currents, a form of apparatus was fitted up which—while it would settle the question indisputably—would at the same time be likely to afford information of much interest.

By chemical means I obtained in an apparatus a vacuum so nearly perfect that it would not carry a current from a Ruhmkorff's coil when connected with platinum wires sealed into the tube. In such a vacuum the repulsion by heat was still found to be decided and energetic.

I next tried experiments in which the rays of the sun, and then the different portions of the solar spectrum, were projected on to the delicately-suspended pith-ball balance. *In vacuo* the repulsion by a beam of sunlight is so strong as to cause danger to the apparatus, and resembles that which would be produced by the physical impact of a material body.

A simpler form of the apparatus for exhibiting the phenomena of attraction in air and repulsion in a vacuum consists of a long glass tube, *a b* (Fig. 3), with a globe, *c*, at one end. A light index of pith, *d e*, is suspended in this globe by means of a cocoon fibre.

When the apparatus is full of air at ordinary pressure, a ray of

[1] This can be effected without interfering with the exhaustion.

heat or light falling on one of the extremities of the bar of pith gives a movement indicating attraction. When the apparatus is exhausted until the barometric gauge shows a depression of twelve millimetres below the barometer, neither attraction nor repulsion results when radiant light or heat falls on the pith, but, when the vacuum is as good

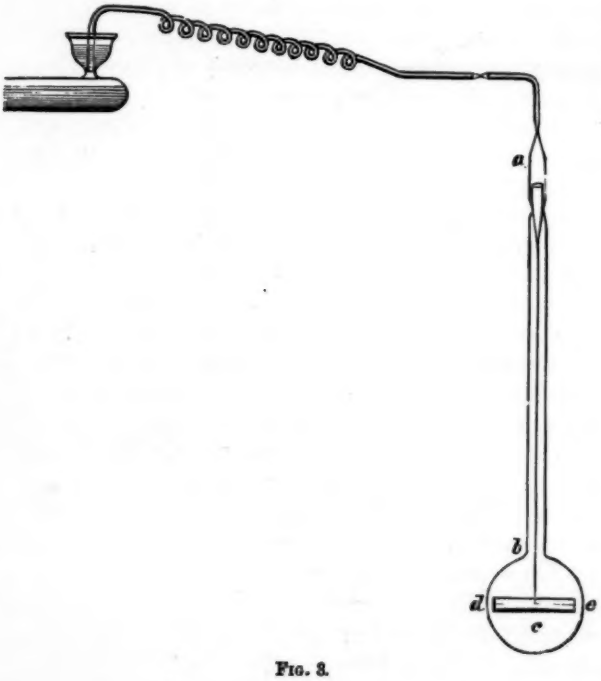


FIG. 3.

as the pump will produce, strong repulsion is shown when radiation is allowed to fall on one end of the index. An apparatus of this kind, constructed with the proper precautions, and sealed off when the vacuum is perfect, is so sensitive to heat that a touch with the finger on a part of the globe near one extremity of the pith will drive the index round over 90°, while it follows a piece of ice as a needle follows a magnet. With a large bulb, very well exhausted, and containing a suspended bar of pith, a somewhat striking effect is produced when a lighted candle is placed about two inches from the globe. The pith-bar commences to oscillate to and fro, the swing gradually increasing in amplitude until the dead-centre is passed over, when several complete revolutions are made. The torsion of the suspending fibre now offers resistance to the revolutions, and the bar commences to turn in the opposite direction. This movement is kept up with great energy and regularity as long as the candle burns.

For more accurate experiments I prefer making the apparatus dif-

ferently. Fig. 4 represents the best form: *a b* is a glass tube, to which is fused at right angles another narrower tube, *c d*; the vertical tube is slightly contracted at *e*, so as to prevent the solid stopper *d*—which just fits the bore of the tube—from falling down. The lower end of the stopper, *d e*, is drawn out to a point; and to this is cemented

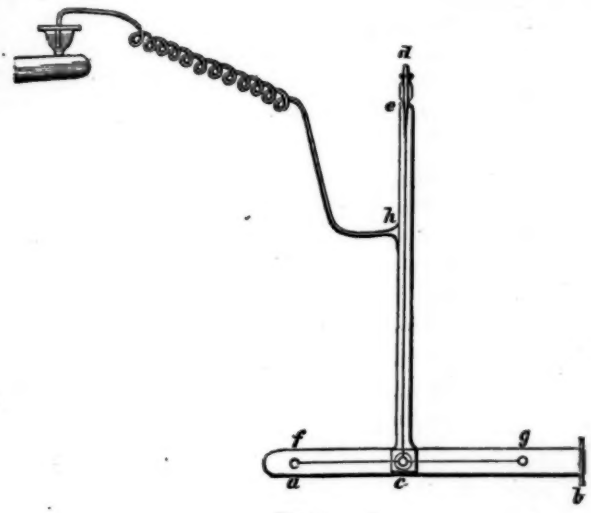


FIG. 4.

a fine glass thread, about 0.001 inch diameter, or less, according to the torsion required.[1]

At the lower end of the glass thread an aluminium stirrup and a concave glass mirror are cemented, the stirrup being so arranged that it will hold a beam, *f g*, having masses of any desired material at the extremities. At *c* in the horizontal tube is a plate-glass window cemented on to the tube. At *b* is also a piece of plate-glass cemented on. Exhaustion is effected through a branch-tube, *h*, projecting from the side of the upright tube. This is sealed by fusion to the spiral tube of the pump. The stopper *d e* and the glass plates *c* and *b* are well fastened with a cement of resin and bees'-wax.

The advantage of a glass-thread suspension is that the beam always comes back to its original position.

An instrument of this sort, perfectly exhausted and then sealed off, is shown at work in Fig. 5. It has pith-plates at the extremities of the torsion-beam. A ray of light from the lamp is thrown on to the central mirror, and thence reflected on to the graduated scale. The approach of a finger to either extremity of the beam causes the

[1] Some of the glass fibres used in these torsion-balances are so fine that when one end is held between the fingers the other portion floats about like a spider's thread, and frequently rises until it takes a vertical position.

luminous index to travel several inches, showing repulsion. A piece of ice brought near causes the spot of light to travel as much in the opposite direction. In order to insure the luminous index coming accurately back to zero, extreme precautions must be taken to keep all extraneous radiation from acting on the torsion-balance. The whole apparatus is closely packed round with a layer of cotton-wool about six inches thick, and outside this is arranged a double row of Winchester quart-bottles, filled with water, spaces only being left for the radiation to fall on the balance and for the index ray of light to get to and from the mirror.

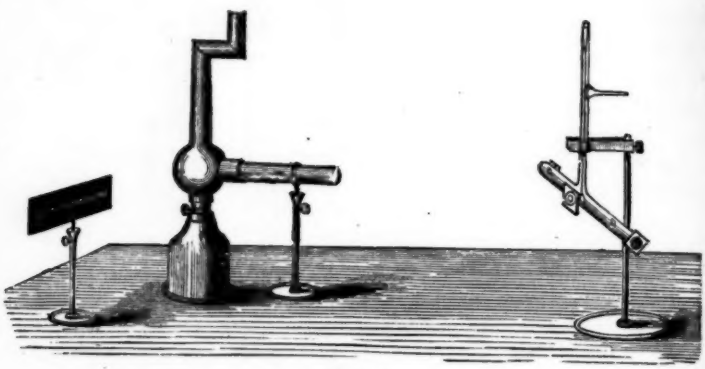


FIG. 5.

However much the results may vary when the vacuum is imperfect, with an apparatus of this kind they always agree among themselves when the residual gas is reduced to the minimum possible; and it is of no consequence what this residual gas is. Thus, starting with the apparatus full of various vapors and gases, such as air, carbonic acid, water, iodine, hydrogen, ammonia, etc., there is not found, at the highest rarefaction, any difference in the results which can be traced to the residual gas. A hydrogen vacuum appears the same as a water or an iodine vacuum.

The neutral point for a thin surface of pith being low, and that for a moderately thick piece of platinum being high, it follows that at a rarefaction intermediate between these two points pith will be repelled, and that platinum will be attracted by the same beam of radiation. This has been proved experimentally. An apparatus showing simultaneous attraction and repulsion by the same ray of light is illustrated in Fig. 6.

The pieces *f g* on the end of one beam consist of platinum-foil exposing a square centimetre of surface, while the extremities *f' g'* on the other beam consist of pith-plates of the same size. A wide beam of radiation thrown in the centre of the tube on to the plates *g f'* causes *g* to be attracted and *f'* to be repelled, as shown by the

light reflected from the mirrors, *c c'*. The atmospheric pressure in the apparatus is equal to about forty millimetres of mercury.

In a torsion-apparatus similar to the one shown in Figs. 4 and 5 I have submitted variously-colored disks to the action of the different rays of the spectrum. The most striking results, as yet, have been obtained when the different rays of the spectrum were thrown on white and on black surfaces. The result was to show a decided difference between the actions of light and of radiant heat. At the highest exhaustions dark heat from boiling water acts almost equally on white pith and on pith coated with lamp-black, repelling either with about the same force. The action of the luminous rays, however, is different. These repel the black surface more energetically than they do the white surface, and, consequently, if in such an apparatus as is

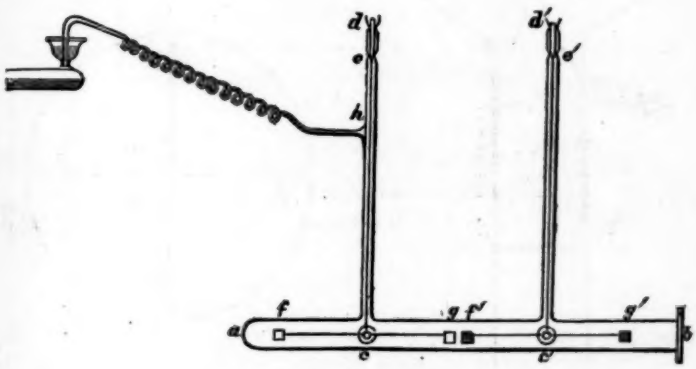


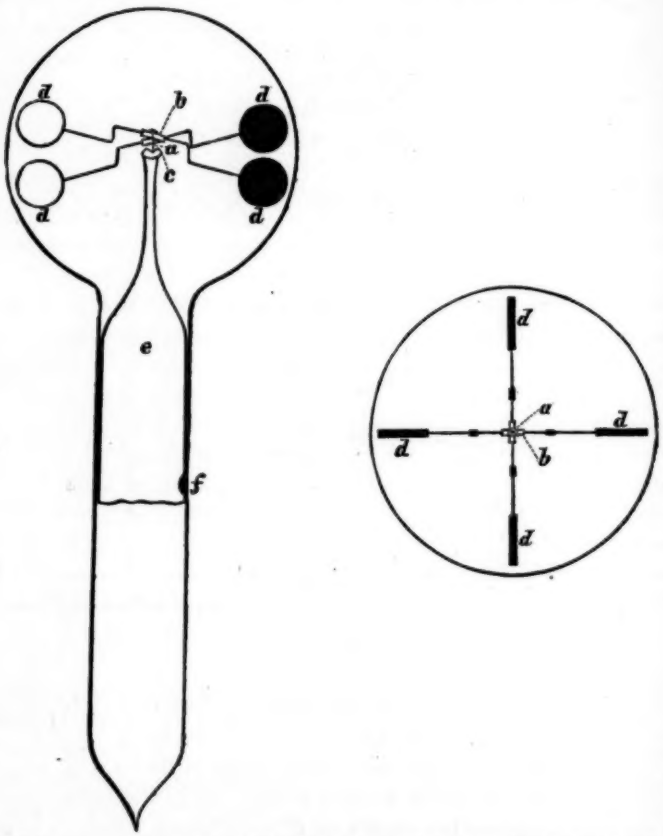
Fig. 6.

shown at Fig. 4, one disk of pith is white and the other is black, an exposure of both of them to light of the same intensity will cause the torsion-thread to twist round, owing to the difference of repulsion exerted on the black and the white surface. If, in the bulb-apparatus shown in Fig. 3, the halves of the pith-bar are alternately white and lamp-blacked, this differential action will produce rapid rotation in one direction, which keeps up until stopped by the torsion of the suspending fibre.

Taking advantage of this fact I have constructed an instrument which I have called the Radiometer, shown in section and plan at Figs. 7 and 8. It consists of four arms, of some light material, suspended on a hard steel point resting in a jewel-cup, so that the arms are able to revolve horizontally upon the centre pivot, in the same manner as the arms of Dr. Robinson's anemometer revolve. To the extremity of each arm is fastened a thin disk of pith, white on one side and lamp-blacked on the other, the black surfaces of all the disks facing the same way. The whole is inclosed in a thin glass globe,

which is then exhausted to the highest attainable point and hermetically sealed.

The arms of this instrument rotate with more or less velocity under the action of radiation, the rapidity of revolution being directly proportional to the intensity of the incident rays. Placed in the sun,



FIGS. 7 and 8.—*a*, a very fine needle-point; *b*, two pieces of straw; *c*, jewel-cup; *d*, *d*, *d*, *d*, four pith-disks, blackened on one side. The arms between the straw in the centre and the disks are bent glass-fibres; *e*, glass support holding cup; *f*, cement to keep the support *c* in its place.

or exposed to the light of burning magnesium, the rapidity is so great that the separate disks are lost in a circle of light. Exposed to a candle twenty inches off another instrument gave one revolution in 182 seconds; with the same candle placed at a distance of ten inches off the result is one revolution in 45 seconds; and at five inches off one revolution was given in 11 seconds. Thus it is seen that the mechanical action of radiation is inversely proportional to the square of the distance. At the same distance two candles give exactly double, and three candles give three times the velocity given by one candle, and

so on up to twenty-four candles. A small radiometer was found to revolve at the velocities shown in the following table, when exposed to the radiation of a standard candle five inches off:

Time required for One Revolution.

Source of Radiation.	Time in Seconds.
1 candle, 5 inches off, behind green glass	40
" 5 " " blue "	38
" 5 " " purple "	28
" 5 " " orange "	26
" 5 " " yellow "	21
" 5 " " light-red "	20

In diffused daylight the velocity was one revolution in from 1.7 seconds to 2.3 seconds, according to the intensity of the incident rays. In full sunshine, at 10 A. M., it revolved once in 0.3 second, and at 2 P. M. once in 0.25 second.

When heat is cut off by allowing the radiation to pass through a thick plate of alum, the velocity of rotation is somewhat slower, and when only dark heat is allowed to fall on the arms (as from a vessel of boiling water) no rotation whatever is produced.

In all respects, therefore, it is seen that the radiometer gives indications in strict accordance with theory.

Several radiometers, of various constructions as regards details, but all depending on the above-named discovery, have been exhibited at the Royal Society, where their novelty and unexpected indications excited a considerable amount of interest.

This form of instrument is of too recent a construction for me to be able to do more than draw brief attention to a few of the many uses for which it is applicable.

By timing the revolutions of the instrument when exposed direct to a source of light—a candle, for instance—the total radiation is measured. If a screen of alum is now interposed, the influence of heat is almost entirely cut off, the velocity becomes proportionately less, and the instrument becomes a photometer. By its means photometry becomes much simplified; flames the most diverse may readily be compared between themselves or with other sources of light; a "standard candle" can now be defined as one which at x inches off causes the radiometer to perform y revolutions per minute, the values of x and y having previously been determined by comparison with some ascertained standard; and the statement that a gas-light is equal to so many candles may, with more accuracy, be replaced by saying that it produces so many revolutions.

To photographers the radiometer will be invaluable. As it will revolve behind the orange-colored glass used for admitting light into the so-called dark-room, it is only necessary to place one of these instruments in the window to enable the operator to see whether the

light entering his room is likely to injure the sensitive surfaces there exposed; thus, having ascertained by experience that his plates are fogged, or his paper injured, when the revolutions exceed, say, ten a minute, he will take care to draw down an extra blind when the revolutions approach that number. Still more useful will the radiometer be in the photographic gallery. Placing an instrument near the sitter at the commencement of the day's operations, it is found that, to obtain a good negative, the lens must be uncovered—not for a particular number of seconds—but during the time required for the radiometer to make, say, twenty revolutions. For the remainder of the day, therefore, assuming his chemicals not to vary, the operator need not trouble himself about the variation of light; all he has to do is to watch the radiometer and expose for twenty revolutions, and his negatives will be of the same quality,[1] although at one time it may have taken five minutes, and at another not ten seconds, to perform the allotted number.

I have long been experimenting in the endeavor to trace some connection between the movements of attraction and repulsion above alluded to and the action of gravitation in Cavendish's celebrated experiment. The investigation is not sufficiently advanced to justify further details, but I will give here an outline of one of the results.

I find that a heavy metallic mass, when brought near a delicately-suspended light ball, attracts or repels it under the following circumstances:

I. *When the ball is in air of ordinary density.*
   a. If the mass is *colder* than the ball, it *repels* the ball.
   b. If the mass is *hotter* than the ball, it *attracts* the ball.

II. *When the ball is in a vacuum.*
   a. If the mass is *colder* than the ball, it *attracts* the ball.
   b. If the mass is *hotter* than the ball, it *repels* the ball.

The density of the medium surrounding the ball, the material of which the ball is made, and a very slight difference between the temperatures of the mass and the ball, exert so strong an influence over the attractive and repulsive force, and it has been so difficult for me to eliminate all interfering actions of temperature, electricity, etc., that I have not yet been able to get distinct evidence of an independent force (not being of the nature of heat or light) urging the ball and the mass together.

Experiment has, however, shown me that, while the action is in one direction in dense air, and in the opposite direction in a vacuum, there is (as I have already pointed out in the experiments described in the commencement of this paper) an intermediate pressure at which differences of temperature appear to exert little or no interfering ac-

[1] In this brief sketch I omit reference to the occasions in which the ultra-violet rays diminish in a greater proportion than the other rays.

tion. By experimenting at this critical pressure, and at the same time taking all the precautions which experience shows are necessary, it would seem that such an action as was obtained by Cavendish, Reich, and Baily, should be rendered evident.

It is not unlikely that in the experiments here recorded may be found the key of some as yet unsolved problems in celestial mechanics. In the sun's radiation passing through the *quasi* vacuum of space we have the radial repulsive force, possessing successive propagation, required to account for the changes of form in the lighter matter of comets and nebulæ, and we may learn by that action, which is rapid and apparently fitful, to find the cause in those rapid bursts which take place in the central body of our system; but until we measure the force more exactly we shall be unable to say how much influence it may have in keeping the heavenly bodies at their respective distances.

So far as repulsion is concerned, we may argue from small things to great, from pieces of pith up to heavenly bodies; and we find that the repulsion shown between a cold and warm body will equally prevail, when for melting ice is substituted the cold surface of our atmospheric sea in space, for a lump of pith a celestial sphere, and for an artificial vacuum a stellar void.

Throughout the course of these investigations I have endeavored to remain unfettered by the hasty adoption of a theory, which, in the early stages of an inquiry, must almost of necessity be erroneous. Some minds are so constituted that they seem impelled to form a theory on the slightest experimental basis. There is then great danger of their becoming advocates, and unconsciously favoring facts which seem to prove their preconceived ideas, and neglecting others which might oppose their views. This is unfortunate, for the mind should always be free to exercise the judicial function, and give impartial weight to every phenomenon which is brought it. *Any* theory will account for *some* facts; but only the true explanation will satisfy *all* the conditions of the problem, and this cannot be said of any theory which has yet come to my mind.

My object at present is to ascertain facts, varying the conditions of each experiment so as to find out what are the necessary and what the accidental accompaniments of the phenomena. By working steadily in this manner, letting each group of experiments point out the direction for the next group, and following up as closely as possible, not only the main line of research, but also the little by-lanes which often lead to the most valuable results, after a time the facts will group themselves together and tell their own tale; the conditions under which the phenomena invariably occur will give the laws; and the theory will follow without much difficulty. The eloquent language of Sir Humphry Davy contains valuable advice, although in terms somewhat exaggerated. He says: "When I consider the va-

riety of theories which may be formed on the slender foundation of one or two facts, I am convinced that it is the business of the true philosopher to avoid them altogether. It is more laborious to accumulate facts than to reason concerning them; but one good experiment is of more value than the ingenuity of a brain like Newton's."—*Quarterly Journal of Science.*

THE CAUSE OF THE LIGHT OF FLAMES.

By W. STEIN.

THE correctness of the old and well-founded conception that the light of flame is caused by incandescent carbon-molecules, has been disputed by Dr. Frankland, who contends and tries to prove that it is derived from hydrocarbon-vapors. It is evident that the old theory would have to give place to the new doctrine as soon as the untenability of the former and the correctness of the latter are proved. But neither the one nor the other has, I think, yet been done. Prof. Frankland can, therefore, only be pleased if the present paper subjects the *pros* and *cons* of the new and old theory to an impartial examination.

As proof of his ideas he mentions that the soot deposited on a cool surface, when introduced into a flame, does not consist of pure carbon, but that it contains also hydrogen; that, in fact, it seems nothing else than a collection of the densest light-giving hydrocarbons, whose vapors condense on the cold surface.

Against this we may mention that not only do the heavy hydrocarbons, but even marsh-gas, split up at high temperatures on exclusion of atmospheric air; and as the hydrocarbons, whose vapors are supposed to cause the luminosity of the flame, are precisely under such conditions before they come into contact with the air, it cannot be doubted that they suffer decomposition into carbon and hydrogen in the luminous portion of the flame. It is of little importance whether the eliminated carbon is chemically pure, or whether it contains still a hydrogen compound; the important question is this, Is the soot held by the flame in the shape of vapor or in the solid form? If the soot was nothing but a conglomeration of the densest light-giving hydrocarbons, whose vapors condense on a cool body, then, when sufficiently highly heated by exclusion of air, it ought to reassume vapor-form. This is, however, not the case, as every one will find who tries the experiment.

Its chemical composition is just as little favorable to Frankland's view. It ought, presumedly, to vary according to the lighting material from which it was derived—nay, even according to the place of

the flame wherefrom it was deposited. It is well known that the temperature of the flame varies in various places, and Magnus's experiments have proved that from heavy hydrocarbons at a less high temperature a hydrogenous tarry product besides hydrocarbon is also eliminated. The soot, whose analysis I give, was obtained from a bat's-wing burner by allowing a small silver basin, filled with water, to dip for about two or three minutes in the flame. Benzine removed traces of a solid yellow body, but the small amount of it prevented its being further investigated. Alcohol, and alcoholic solution of caustic potash, and dilute sulphuric acid, dissolved nothing.

After being carefully and repeatedly washed with boiling water and dried at 130°, 0.206 yielded: Carbonic acid, 0.6985; water, 0.0195; ash, 0.0020—which amounts in 100 parts to.

	Containing Ash.	Free from Ash.
Carbon	96.446	97.390
Hydrogen	1.051	1.061
Ash	0.970	.....
Oxygen	1.533	1.533

I attribute the presence of oxygen to a small amount of water, which, even at 130°, was still retained, and this, when deducted, gives the composition of 100 parts of soot free from water and ash as consisting of carbon, 99.095; hydrogen, 0.905.

This analysis is in accordance with the chemical composition of the soot of the flame, and with the well-known behavior of heated hydrocarbons.

2. "How could the light of a flame be as transparent as in reality it is, if it was filled with solid carbon-particles?" asks Dr. Frankland.

In reply to this, it must be admitted that one is able to read the writing held behind the flame of a bat's-wing burner. It is, however, easily observable that the flame is more transparent in the lower non-luminous portion. The reading becomes also more difficult through a flame of greater thickness, and impossible through the flame of a candle or petroleum-burner. If, as is proved hereby, the transparency of a flame is only very limited, it may also be remembered that one can also read the same writing through media which are known to be filled with solid particles. The fact that solid bodies are by preference apt to become light-radiating is not at all changed by this, and thus far it is demonstrated only that there can be but one solid body to which the luminosity of flame can be attributed. If we consider, therefore, all the facts, we can draw only one conclusion, namely, that the light of our illuminating flame comes from incandescent carbon-molecules, and that the old view is still to be retained.

Experience teaches that, for the artificial production of light, a high temperature is requisite before all things. Temperature is, however, that part of the total heat of a body which influences the surrounding

parts, or the surplus of atomic movement which is not consumed by its inner work. A high temperature means, therefore, a great excess of such movement, which again is identical with a greater number of momentary vibrations. In fact, the movement of light and the movement of heat differ essentially by regularity (*rhythmen*), and greater movement of heat passes, therefore, presumedly into movement of light, if it has reached the lowest number of vibrations for light, namely, those of red light. If, after a greater and greater rising of temperature up to its highest possible degree, the rapidity of movement increases more and more, we observe, besides the red light, first, yellow light, forming orange with the former; later, we meet also blue light, which, however, in most cases, only serves to form white light with the red and yellow, and which is only predominant in very rare cases, as observed by Deville. Under ordinary circumstances, we only get a yellow or red light containing more or less white. The more white it contains the greater is, naturally, its effect of light; and, as white only appears at the highest temperatures, it becomes evident that the temperature of a flame does not exert a secondary influence on its luminosity, but is its principal factor. The second factor is the eliminated carbon, the molecules of which radiate the light. The luminosity of two flames of the same temperature corresponds, therefore, to the number of its carbon-molecules, and "luminosity in general equal to the product of the radiating molecules and their temperatures" for illuminating purposes, it may be presumed that the latter should amount to at least 1,000°.

The above-mentioned phenomena of light may easily be observed on solid bodies if heated. They are not observable on gases as long as they expand unhindered. It would, however, be wrong to attribute this negative behavior to the circumstance alone that, by the unhindered expansion, the amount of the added or produced heat was changed into power. This is contradicted by the high temperature which, among others, the non-luminous explosive gas-flame (*Knallgas*) possesses. Besides, it is also observed that platinum wire becomes incandescent in every possible non-luminous flame, even in a flame produced by nitrogen on coal-gas, if the requisite temperature to change heat into light is present.

If we may conclude from this that the atoms of gases may be brought into light-vibrations without becoming luminous, then we possess bodies which conduct the light (the gases), and others which radiate light (the solid bodies), just as we have conductors of electricity and idio-electrical bodies.

An explanation of this difference is offered when light is considered as atomic movement. Its effect to the eye is then the product of quantity and velocity.

In a given space we find a much larger number of vibrating atoms if filled with solid matter than if filled with gas. The waves of light

of solid bodies must, therefore, be much denser than those of gases, and exert also a more intense effect on the nerves of our eyes. "Light-conductors" differ, therefore, from "light-radiators" by the lesser density of their waves of light; for which reason they cannot, under ordinary circumstances, form "optical molecules," as I expressed on another occasion. How powerfully the condensation of the waves of light affects the eye is shown by the effect of collecting lenses.

The minimum of density which a body must possess to become light-radiating—that is, to become self-luminous to the eye, or to appear a source of light—is just now not known; but one sees, if this view is correct, the possibility of even vapors or dense gases becoming luminous, as Frankland tried to prove. The results of his experiments might even serve as foundation for the lowest limit of density, if it were not so very difficult, nay, even just now impossible, to make such an experiment in a manner so as to exclude every doubt about the assisting influence of solid bodies.—*English Mechanic.*

MENTAL DISCIPLINE IN EDUCATION.

By A. G. MERWIN.

I THINK it is safe to assume, on the one hand, that all, or nearly all, mental discipline is of value; and, on the other, that all, or nearly all, knowledge is of value. It will also be conceded that a life spent in disciplining the mind, while the mind so disciplined is never employed in the direction of utility, is a life wasted. It seems equally true that utility, when so narrowed as to relate only to the outward trappings of the human being, is not real utility.

By mental discipline we mean nothing more than habit of mental action. The disciplined mind does not differ in kind from the undisciplined any more than the strength of a man differs in kind from the strength of a child. It is evident that the best mental discipline must be that which prepares the mind to grasp and direct the facts, realities, and influences, on which human well-being depends.

It is thought that there is study which gives mental power or discipline, while it results in little useful knowledge. By a method of study the mind is to be developed into an intellectual Samson, but a blind Samson; and it is hoped and believed that a mind so trained will do something better than to involve itself and others in a common ruin. That is, it is assumed that a habit of thought which does not lead to useful knowledge in school, is the habit of thought which will lead to useful knowledge in common affairs of life.

The study of a dead language is supposed to give this mental discipline. Such study has almost nothing to do with present realities.

It trains the mind to look, not so much at the thought as at the manner of expressing the thought. It deals with the tools of thought rather than the thought itself. For years the mind is habituated to work upon those things which must be discarded as soon as school-life is ended; and this is called education. It is not to be denied that such discipline is better than no discipline. It is conceded that such discipline does aid the student in the use of language. But of what value is a discipline which, while it gives power or facility in the use of language, gives little power to investigate those things for which language was made?

Language is the implement of thought, and it would seem that no study of this implement can give the best training for studying the thought itself, or the reality that lies back of the thought. It is probable that the highest efforts of the mind, those efforts in which new truths have flashed out, then vanished, then returned again, until the investigator has finally made them his own, have been made without the aid of language. Language is a medium between man and man, not necessarily between man and Nature. Thoughts which come to us through language must come to us at second-hand. Language, being the medium of thought, cannot precede thought.

Not that the study of language, when pursued in relation to the thought, is of little value; but the folly is in the prolonged study of a language which, with rare exceptions, can never be a highway of knowledge nor a medium of thought. What is the value of words? Words mean the same to those persons only who have had the same experiences. Words do not convey ideas; they suggest them. When a word is spoken, the hearer is at first conscious of sound. If he has been accustomed to associate the spoken word with some idea, the mind instantly represents the idea. If the experience of both speaker and hearer has been the same, the word has the same meaning to each. In the mind of the speaker the idea suggests the word; in the mind of the hearer, the word suggests the idea. No word ever explains any sensation, pleasant or painful, to one who has never felt the sensation. By aid of the imagination we may, to an extent, give meaning to language that does not directly appeal to experience; but the imagination can do nothing more than recombine materials that have been furnished by experience, so that directly or indirectly words derive their meaning from experience; and words have a common meaning because they suggest ideas of a common experience.

It seems to follow that the real value of language must depend upon the amount of knowledge attained. To make the study of language the principal means to an education appears as irrational as to gather stores of the implements of husbandry in the midst of a desert waste—as irrational as to expect to make a skilled mechanic by setting him to study the tools of his trade. Much more irrational does this appear when the language is one in which the mind never does

its work, and which contains at best but the literature, philosophy, and fables of a past age.

I do not mean to disparage language as a means of influencing action and recording thought; but why spend years in the study of languages which we never use to influence action or record thought, under the plea that this study disciplines the mind for useful work? Can useless work produce useful habits? It must not be forgotten, however, that the power of language is greatest where there is least knowledge. It is not difficult to show that the influence of oratory declines as intelligence increases. Men seldom engage in oratory where positive knowledge leaves no play for the imagination. Indeed, science is constantly devising plans to avoid the verbiage of ordinary statement; hence the mathematics. The same general truth appears in the proverb, "A word to the wise." The very word "demagogue" is a warning that we should beware of the specious arts of the orator. Language presupposes thought; a community of language presupposes a community of thought and experience. While correct thinking may exist without correct speaking, it needs but the observation of every day to show that correct and truthful speaking never can exist without correct thinking.

It is pertinent to inquire here by what discipline society has progressed toward the most excellent things. Undoubtedly by the discipline of experience, or it might be called the discipline of environments. Men have not marked out the course of human progress, nor have they, to any considerable extent, been able to forecast it. Two thousand years ago, who would have believed that the northern barbarians would surpass Greece and Rome?

We cannot go back to the ultimate cause, and tell why one class of the human family should progress and another retrograde or remain stationary. We may point out some of the conditions of progress; but the germ of that progress we do not know. We may believe that the best organized and most intelligent communities, by resulting strength, overcome the more poorly organized and less intelligent. We still ask, How came these communities better organized? Why did not this organization occur a thousand years earlier or a thousand years later? We reply, the conditions were not favorable. What do we mean when we say the conditions were not favorable? We mean that there is a certain correspondence or relation between human activities and outlying natural forces. These correspondences and relations are the problems of progress. As yet, we can do little toward their solution.

This much we observe, that in all progress discipline has not been an end but an incident of study. The discipline was attained by man in studying his environments and in altering his relation to those environments. Further, men attained a comparatively high state of mental discipline before schools existed at all.

Again, schools and education, technically so called, are not the antecedent but the consequent of progress. The men who have been most successful in penetrating the secrets of Nature and solving the problems of society have been in advance of any school. The education of these men has not been for mental discipline; they have studied to find the truth, and an incident of that study has been discipline. Whence came that discipline which rendered schools possible? Not from disciplinary studies, certainly. It came in the study of surrounding conditions, with the view to bring those conditions into conformity with what was deemed personal or social well-being. Mental discipline had then the same relation to human activity that it has now. Until schools were created, all study was in the direction of real or apparent utility; all study outside of the schools is at present for knowledge or utility.

That is, the law of education has been and is now, that mental discipline is the incident and not the end of study. Hence the conclusion, study what is most useful, and the resulting discipline will be most valuable.

We see the same truth in another aspect when we observe that the highest mental and physical power is attained in efforts to discover, measure, and control the forces around us. A language is never so easily or so well learned as when our personal comfort depends upon its use. The hand and eye of the hunter are never so thoroughly disciplined as when he knows that at any moment his life may depend on the accuracy of his aim. The mathematics have been invented to measure the relations of things in common life, or to investigate the less apparent relations.

I cannot forbear here to point out, further, that the truth in regard to mental discipline appears to be a universal truth or law of human activity, perhaps of all activity. Discipline is an incidental result of right exercise. In accordance with this truth are developed and disciplined the religious, intellectual, physical, social—indeed, every faculty and capacity within us. This law recognized, and science and philosophy will force us to accept the best truths of religion—those truths which take man out of himself, make him forgetful of himself, and teach him that he does most for himself who does most for others. Upon such a general truth appears to rest the proposition that we should study for utility—for utility in its widest and best sense—and not for discipline. In the light of this truth we recognize the dead languages—all languages—the mathematics, as but the means, the machinery of an education. Resting on experience, they direct us to new experience. These are the glass through which we may see something of ourselves and the universe. Why waste half our lives in studying the glass under pretense of disciplining our eyes, when our eyes would be better disciplined by studying Nature beyond? Better still to break through all barriers, and study things them-

selves, using the records of other men's experience as we may need them.

Again, mental discipline is mental habit. How do we form habits that are desirable? Not by seeking some course of activity that shall create the habit, but by trying to do something that is desirable. Useful habits are incidental results of doing useful work. The mechanic does not use extra care that he may form habits of accuracy, but that he may produce better work. The astronomer does not make his observations with the view of forming habits, but to learn the phenomena of the heavens; and if he be called upon to observe some phenomenon that occurs but once in a lifetime, he will hardly think of seeking that special discipline which the observation may require by studying the conjugation of the Greek verb.

I think we meet this fact everywhere out of the schools, that discipline is not sought as an end. The idea of discipline for its own sake was asceticism in religion. Men sought moral excellence by retiring from the world, and contemplating the things within them. The same idea of discipline led men to look for knowledge within themselves, instead of seeking it by observing things around them. But the system failed in religion and morals, as it failed in discovering truth and educating the intellect. We see why it must fail; it wastes the energies of the individual in acting upon his own powers. What is progress in its last analysis? Is it not change of relation? We are superior to our savage ancestors, because our relations to society and the forces of Nature differ from theirs. What is knowledge but a mental accumulation of true relations? What is reason but the power to compare relations, and what is wisdom but the ability to perceive true relations, and direct our actions in accordance with them? Discipline, habit, and character, appear to be activity crystallized in seeking adaptation to our environments. What is the truth that stands out in relief? Clearly, that character, habit, and discipline, are the reflex upon ourselves of activity, moral, mental, or physical. Whence it seems to follow that useless or vicious activity will appear as useless or vicious character and discipline. On the other hand, we may be sure that the study of those things which it is most important we should know, and the activities which it is most important we should pursue, will give the best discipline, the most valuable habits, and the most excellent character.

The conclusion appears to be that mental discipline is an incident of right education, never an end.

The real educational question is, not of the value of discipline, but of the relative values of the different kinds of knowledge. When we learn what knowledge is most valuable, the habit or discipline incidentally acquired in seeking that knowledge will, no doubt, be the discipline which will aid most in seeking and applying other valuable knowledge throughout the whole course of life.

THE COLORADO POTATO-BEETLE.

By Prof. C. V. RILEY.

FEW insects have done more serious injury, or attracted greater attention, than this, even in America, where insect depredations attain a magnitude scarcely dreamed of in this country. Feeding originally on the wild *Solanumr ostratum* in the Rocky Mountain regions of Colorado and other Territories, it fell upon the cultivated potato as soon as civilized man began to grow this esculent within its reach. With large fields of palatable food, instead of scattered plants of the wild *Solanum*, to work upon, it multiplied at a marvelous rate, and began to spread from its native home toward the East. Reaching a point 100 miles west of Omaha, Nebraska, in 1859, its progress has been carefully recorded each year since, until last year it reached the Atlantic coast at a number of different points in Connecticut, New Jersey, New York, Pennsylvania, Delaware, Maryland, and Virginia. The present year we hear of it being still more numerous on the Atlantic coast, and of its swarming around New York City, and covering the nets of fishermen. It has thus, in sixteen years, spread over 360 geographical miles, in a direct line; and, if we consider the territory

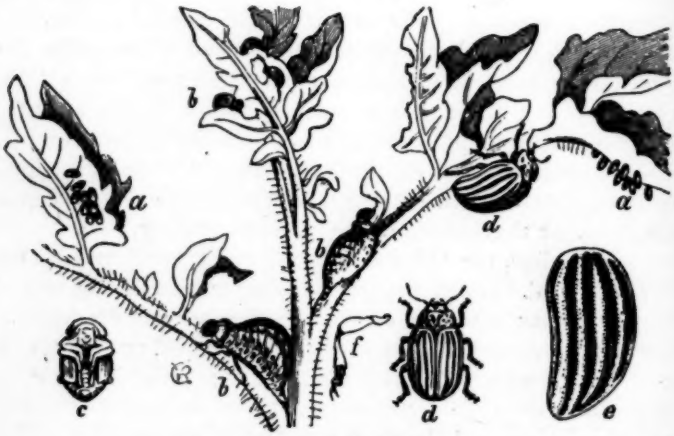


Fig. 1.—Colorado Potato-Beetle.

a, *a*, eggs; *b*, *b*, *b*, larvæ of different sizes; *c*, pupa; *d*, *d*, beetle; *e*, left-wing cover magnified to show lines and punctures; *f*, leg enlarged. Colors: of egg, orange; of larvæ, Venetian-red; of beetle, black and yellow.

actually invaded, which includes the States of Kansas, Nebraska, Missouri, Iowa, Minnesota, Wisconsin, Illinois, Indiana, Kentucky, Michigan, Ohio, Ontario (Canada), New York, Vermont, Massachusetts, Pennsylvania, Maryland, and Virginia, it has overrun an area of 800,000 square miles. The natural history of the species was first

made known by me in 1863. The beetle hibernates either beneath the ground or beneath any other shelter that it can obtain. Early in spring it issues from its winter quarters, and may be seen flying about, on sunny days, long before there are any potato-tops for it to devour. In flight it presents a very pretty appearance, its gauzy, rose-colored under-wings contrasting agreeably with the striped yellow and black elytra or wing-covers. The sexes pair, and, as soon as the potato haulms push out of the ground, these beetles break their long winter fast, sometimes even working their way down toward the sprout before it is fairly out of the earth. The eggs, which are orange-yellow, are laid in small clusters on the under sides of the leaves, and the same female continues to thus lay at short intervals for a period of over forty days, until the number laid by a single specimen may aggregate from 500 to over 1,000. There are, in the latitude of St. Louis, three broods each year; but, from the fact that a single female continues to deposit as above described, and from the irregularity of larval development, the insect may be found in all stages throughout the summer months. In from thirty to forty days from the time the egg is deposited, the insect hatching from it goes through all its transformations and become a beetle, the pupa state being assumed underground. The prolificacy of the species may be imagined when it is remembered that the progeny of a single female may exceed a hundred millions in the course of a single season! The beetle feeds as well as the larva, though not so voraciously. Its attacks are principally confined to plants of the family *Solanaceæ*, and it is particularly fond of those belonging to the genus *Solanum*. Yet I have recorded many

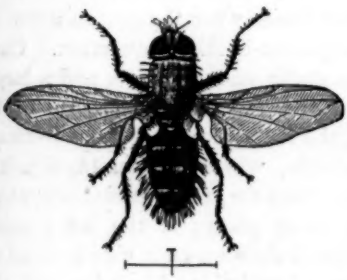


FIG. 2.—LYDELLA DORYPHORÆ; PARASITE OF DORYPHORA. COLORS, SILVER-GRAY AND BLACK.

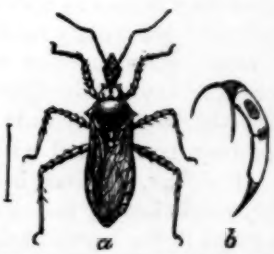


FIG. 3.—MANY-BANDED ROBBER; WITH BEAK ENLARGED AT SIDE (*b*). COLORS, PALE YELLOW AND BLACK. PREYS ON DORYPHORA.

instances of its acquiring new habits in its march to the Atlantic, and of its feeding, when hard pushed, on plants of other families. There are various means of destroying the insect, and in the earlier invaded territory of the States, though it continues its ravages, thereby making the cultivation of potatoes more laborious, and increasing their market price, yet it is no longer dreaded as it at first was, for the rea-

son that it is controlled with comparative ease. The natural enemies of the species are encouraged by the intelligent cultivator, and poultry may be taught to feed upon it. Of over twoscore predaceous and parasitic species of its own class which I have enumerated, those herewith figured may be considered the most important. The only true parasite is a species of Tachina-fly (*Lydella doryphoræ*, Riley), somewhat resembling a house-fly, which fastens its eggs to the *doryphora* larva. From these eggs hatch maggots, which feed upon the fatty portions of the said larva, which, after entering the ground, succumbs to its enemy, and, instead of eventually giving forth a beetle, as it naturally should do, gives forth, instead, the Tachina-flies. A number of different lady-birds (*Coccinellidæ*), of which the convergent lady-bird is the most common, devour the eggs of the *doryphora*. Of true bugs the spined soldier-bug (*Arma spinosa*, Dallas) is the most effective, though several other rapacious species assist it, all of them piercing and sucking out the juices of their prey. Of artificial remedies there are various mechanical contrivances for knocking the insects off the haulm and catching them—some such even being worked by horse-power. The sun is, also, so hot in some of the Mississippi Valley States that the larvæ are roasted to death if shaken from the haulm on to the hot soil at mid-day. The remedy of all others, however, and the one universally employed, is Paris-green, which is used either in the form of a powder, or in that of a liquid, being combined in the former case with from twenty-five to thirty parts of some dilutent, as flour-middlings, plaster, etc., and in the latter with one tablespoonful of pure green stirred into an ordinary bucketful or about three gallons of water. Enormous quantities of the poison have thus been used in America, especially since it has proved a perfect remedy for the cotton-worm in the Southern States as well as for the potato-beetle in question. Cautiously and judiciously used it proves cheap and effective, and a large experience goes to show that no ill effects follow such use of it. There is a very closely-allied species, the *Doryphora juncta* of Germar, called the bogus Colorado potato-beetle, which, very naturally, has often been confounded with, and mistaken for, the genuine depredator. It differs, however, in the eggs being paler; in the larva being paler, and in having but one row of black dots on each side instead of two; and in the beetle having the second and third black lines of the elytra (counting from the outside) joined, instead of the third and fourth; in the punctures of said elytra being more regular and distinct, and in the legs having pale instead of dark tarsi, and a spot on the thighs. Singularly enough, this species, though it feeds and thrives on *Solanum Carolinense*, will not touch the cultivated potato, and is, therefore, perfectly harmless to man.

The English reader is more particularly interested in this insect, because of its possible introduction into Europe; and on the subject of its introduction I cannot do better than quote some passages from

my seventh report: "Those who have watched the gradual spread of this potato-beetle during the past seventeen or eighteen years from its native Rocky Mountain home to the Atlantic, and who have seen how lakes, instead of hindering its march into Canada, really accelerated that march, can have no doubt that there is danger of its being carried to Europe. Yet I must repeat the opinion expressed a year ago—and which has been very generally coincided in by all who have any familiarity with the insect's economy—that if it ever gets to Europe it will most likely be carried there in the perfect beetle state on some vessel plying between the two continents. While the beetle, especially in the non-growing season, will live for months without food, the larva would perish in a few days without fresh potato-tops, and would, I believe, starve to death in the midst of a barrel of potatoes, even if it could get there without being crushed; for, while it so voraciously devours the leaves, it will not touch the tubers. The eggs, which are quite soft and easily crushed, could, of course, only be carried over on the haulm or on the living plant; and while there is a bare possibility of the insect's transmission in this way, there is little probability of it, since the plants are not objects of commercial exchange, and the haulm, on account of its liability to rot, is not, so far as I can learn, used to any extent in packing. Besides, potatoes are mostly exported during that part of the year when there are neither eggs, larvæ, nor potato haulm in existence in the United States. There is only one other possible way of transmission, and that is in sufficiently large lumps of earth, either as larva, pupa, or beetle. Now, if American dealers be required to carefully avoid the use of the haulm, and to ship none but clean potatoes, as free from

FIG. 4.—BOGUS COLORADO POTATO-BEETLE.
a, *a*, eggs; *b*, *b*, larva; *c*, beetle; *d*, left-wing cover, enlarged, showing marks and punctures; *e*, leg enlarged. Colors: of egg, pale-yellow; of larva, cream-yellow; of beetle, black, yellow, and brown.

earth as possible, the insect's transmission among the tubers will be rendered impossible; and when such precautions are so easily taken, there can be no advantage in the absolute prohibition of the traffic in American potatoes. As well prohibit traffic in a dozen other commodities, in many of which the insect is as likely to be imported as in potatoes. The course recently adopted by the German Government,

in accordance with the suggestion made in my last report, is more rational, and will prove a better safeguard: It is to furnish vessels plying between the two countries, with cards giving illustrated descriptions of the insect in all stages, with the request that passengers and crew destroy any stray specimens that may be found. Let England and Ireland, together with the other European governments, cooperate with Germany in this plan, and have such a card posted in the warehouses of seaport towns, and the meeting-rooms of agricultural societies, and a possible evil will be much more likely avoided." Some English journals are discussing the question as to whether, with the more moist and cool climate of this country, the ten-line potato-beetle would thrive here even if imported. "There cannot be much doubt that it will rather enjoy the more temperate clime; for while it thrives best during comparatively dry seasons, both excessive heat and drought, as well as excessive wet, are prejudicial to it. It is argued by others that on the Continent of Europe our *doryphora* would not thrive if introduced; and, in a recent letter received from M. Oswald de Kerchove, of Gand, Belgium, author of an interesting pamphlet on the insect, that gentleman says, 'I do not think that the *doryphora*, awakened by our early warm weather, could resist the effects of the late cold which we are apt to have in these European countries.' The idea that the climate of North America is less extreme than that of Europe is rather novel to us of the cisatlantic; and, from a sufficiently long residence in England, France, and Germany, I am decid-

FIG. 5.—SPINED SOLDIER-BUG.
a, beak enlarged; *b*, perfect insect, with the wings expanded on one side. Color, ochreous.

FIG. 6.—CONVERGENT LADY-BIRD.
Larva, pupa, and beetle. Colors, orange, white, and black.

edly of opinion that they delude themselves who suppose that *doryphora* could not thrive in the greater part of Europe; and that to abandon all precautionary measures against its introduction on such grounds would be foolish. An insect which has spread from the high table-lands of the Rocky Mountains across the Mississippi Valley to the Atlantic, and that flourishes alike in the States of Minnesota, Wisconsin, and Connecticut, and in Maryland, Virginia, and Texas—in fact, wherever the potato succeeds—will not be likely to be discomfited in the potato-growing districts of Europe. Some few, again, have ridiculed the idea of the insect's passage to Europe in any state, arguing that it is an impossibility for any coleopterous insect to be thus transferred from one country to another. Considering that half

the weeds of America, and a large proportion of her worst insect pests, including two beetles, viz., the asparagus-beetle (*Crioceris asparagi*) and the elm-leaf beetle (*Galeruca calmariensis*), in the very same family as our *doryphora*, have been imported from Europe, there would seem poor foundation for such an argument. Moreover, a number of other insects—among them some beetles—of less importance, may be included in the number of importations; and the rape-butterfly (*Pieris rapæ*), whose progress westward has been simultaneous with that of the *doryphora* eastward, and whose importation dates back but a few years, bears witness to the fact that insects more delicate, and with fewer chances of safe transport than *doryphora*, may succeed in getting alive from one country to the other, and in gaining a foothold in a new home. The ravages of the insect, bad as they are, very naturally get exaggerated at such a distance from its native home, and the following from an English gardening periodical gives altogether a too gloomy picture: 'When once a field of potatoes has been attacked, all hopes of a harvest must be given up; in a few days it is changed into an arid waste, a mere mass of dried stalks.' It should not be forgotten that the American cultivator, by means of intelligence and a little Paris-green, is pretty much master of the *doryphora*." It is to be hoped that this exposition of the facts and probabilities of the case will put people on their guard, and cause intelligent action to be taken to prevent the importation of so dangerous a pest as this potato-beetle.—*The Garden.*

PASTEUR ON FERMENTATION.[1]

TRANSLATED BY L. A. STIMSON, M. D.

DURING the months of March and April a spirited discussion took place in the Académie de Médecine, at Paris, on fermentation and kindred subjects, in the course of which M. Pasteur was called upon again to sustain and develop his theory of this process, which is now so generally accepted. His share in the discussion was marked by the brilliancy of exposition and accuracy of experiment which have made him perhaps the most formidable debater among our modern *savants*. We have not here the space to speak of the certainty with which he seizes upon the central point of the discussion, and the tenacity with which he clings to it, the rapidity with which he exposes the weak points of an adversary's argument, and the absolute confidence shared even by his bitterest opponents in the accuracy of his experiments and statements. What now follows is the

[1] Bulletin de l'Académie de Médecine, 2d and 9th of March, 1875.

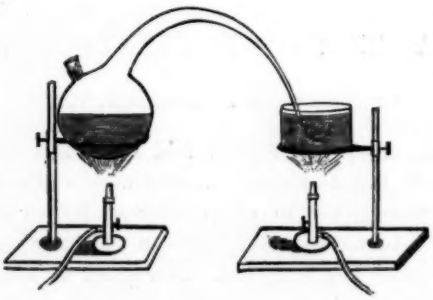
substance of two papers read by M. Pasteur, which have been condensed in the translation only so much as was rendered necessary by the limited space which could be given them.

M. PASTEUR: At the last meeting of the Academy, M. Bouilland asked me the following question: "*What are the ferments of the ferments?*"

Before entering into the details required by the answer to this question, it is indispensable that I recall the results communicated by me to the Académie des Sciences a week ago, for it is a question of life under circumstances hitherto ignored. The gist of the communication to which I refer lies in this proposition—the expression of rigorously-conducted experiments—that there are circumstances under which life may appear and be kept up without the presence of air, and consequently with the entire absence of free oxygen.

Here is a 3-litre flask containing 75 grammes of pure lactate of lime, about half a gramme of the phosphate of ammonia, about 0.4 gramme of the phosphate of potash, 0.3 of the chloride of magnesium, 0.2 of the sulphate of ammonia, and a very small quantity of the sulphate of soda. We may substitute advantageously for all, except the lactate, a salt of ammonia and the ashes of an inferior organism, brewer's yeast, for example.

We boil the liquid contained in the flask, while the extremity of this curved tube, which is so placed that it will collect all the gases that may be liberated, is plunged below the surface of another portion of the same liquid contained in another vessel, which is also boiled at



the same time. The object of this operation is to deprive the contents of the flask entirely of air. We then let it cool and carry the curved end of the tube into a vessel filled with mercury.

This liquid thus arranged would remain inert forever, either protected from contact with the air, as it now is, or in contact with it, provided the air were entirely free from organic dust. Nevertheless it is suitable for the nourishment of certain beings, notwithstanding its purely mineral composition. But life is absent and would

remain absent forever, because that which constitutes essentially the life of those beings, for the nourishment of which this liquid is appropriate, has not been added. Let us then introduce life there, let us sow vibrios in it. We place in the little funnel which surmounts the straight tube of our flask, the one closed by a glass faucet, a small quantity of one of those organic liquids in which vibrios are found after exposure to the air; or, better yet, and that is what has been done here, let us place in the funnel some liquid, the same exactly as that contained in the flask, but which has been exposed to the air and in which vibrios have appeared. Let us now turn the faucet and introduce a few drops with their vibrios into the flask.

Singular phenomena appear soon after this sowing of life in our mineral solution. The liquid, which was as limpid as distilled water, becomes little by little opalescent during the following days, and at the same time gases are set free and rise in the form of small bubbles to the top of the flask. This gas is a mixture of hydrogen and carbonic acid, and at the same time the lactic acid is transformed into butyric acid, which unites with a part of the lime of the lactate, the rest of which combines with the carbonic acid. It is a real putrefaction of the lactic acid which has taken place, but a putrefaction without putridity, for the lactic acid contains neither sulphur nor phosphorus, those elements of offensive gaseous combinations which are deleterious for man but inoffensive for vibrios. No, I am wrong: putridity shows itself, but in so slight a degree that it is almost inappreciable. Phosphorus and sulphur are present in the phosphates and sulphates; these are decomposed, hence a slight odor and even quite frequently a gray color given to the precipitate, probably by a little sulphuret of iron, for iron is almost always present, even in the purest materials.

Whence come all these mysterious transformations? Microscopical examination of a drop of this liquid which has lost its primitive limpidity will tell us. Wonderful spectacle! Beings in the form of small rods go and come, stop and recommence their movements. They are single or united in pairs, twos, threes, and even more. Here are a pair which separate from one another by a sort of effort, more or less prolonged on the part of the two individuals composing it. And now each half has its own movements; this is generation by scission. Now I know why the liquid is milky. What our eyes in their weakness call milkiness the microscope shows us is a consequence of the life of these little beings and of their incessant movements. And the experiment, patiently followed out, will tell us that the life lasts as long as does the principal food of our little beings, that is, the lactic acid of the lactate of lime, provided always that all the other general conditions of existence be satisfied; for it is not enough to have food at our disposal, we must be able to assimilate it, and it is necessary that the functional trouble which you call *pathology* should

not come to interfere with life and health. In a moment, if you choose, I will make them ill, all these little beings.

We have not finished with the peculiarities of our experiment, which will appear the more remarkable and instructive as you study it more closely. Let us weigh the vibrios that have been formed when the process ceases, when all internal movement has disappeared, and when they have fallen inert to the bottom of the flask, because they have exhausted their principal food, the lactic acid, transforming it into butyric acid, which is absolutely unfit for their existence, you will know why in a moment when I describe fermentible materials. Let us compare this weight of the vibrios with that of the 75 grammes of the transformed lactate of lime. The difference is considerable. I cannot now give you the exact figures, but the proportion is at the most as 1 to 200. What does that mean? an agent which causes the decomposition of a weight of matter 200 times as great as itself! But that is the characteristic of the phenomena to which chemists have given the name *phenomena of fermentation.* Yes, we have had to do with a real fermentation, in which the lactic acid is the fermenting substance and the vibrios the ferment.

Who would dare now to maintain that fermentations are phenomena of contact, phenomena of movement communicated by an albuminoid substance which is undergoing change, or of phenomena produced by semi-organized substances which are being transformed into this or into that? All these scaffoldings built by the imagination crumble before our experiment, so simple and so demonstrative.

Still, the most essential and, so to speak, dominant circumstance in our experiment has not yet been introduced, and it is time for me to submit it to your attention.

We prepared at the beginning a nutritive liquid, deprived entirely of air and protected from contact with it; we then sowed vibrios in it, and, during the weeks that have elapsed, our liquid has never been uncovered. Nevertheless, the vibrios have multiplied infinitely. Here, then, is life—that is to say, nutrition and generation—without the slightest aid from air or free oxygen. And in this experiment two things have marched side by side, life without air and fermentation. Ah, if that was a general phenomenon; if life as we know it, with absorption of free oxygen, was not accompanied by fermentation properly so called; if the weight of assimilated food corresponded to that of food ingested and used under the influence of respiration; and if, on the other hand, life without air was always associated with fermentation; if, in the latter case, life resulted in the transformation of an enormous weight of food as compared with the weight of the nutritive assimilation—should we not have raised the veil of these mysterious phenomena of fermentation?

From the moment it should be established that there is correlation between the fact of life without air and the fact of fermentation,

should we not have discovered the cause of this important phenomenon? The real causes of phenomena escape us. In sound philosophy the word *cause* should be reserved for the divine impulse which formed the universe. We can detect only correlations. One phenomenon succeeds another, and cannot exist without its manifestation; by abuse of language we then say there is relation of cause and effect.

Well, it is so. This phenomenon is general. Yes, when there is life without air, there is fermentation, and when there is fermentation there is life without air.

We all know that fruits detached from the tree and exposed to the air live, if we may so express it, like animals and certain inferior plants, for they absorb the free oxygen which surrounds them, and exhale a volume of carbonic-acid gas about equal to that of the oxygen which is introduced into their cells to produce in them certain manifestations of life, for the fruit continues to ripen. That being admitted, let us place a fruit, not in the air, but in carbonic-acid gas. Of two things, one, life, or, if you prefer, a certain chemical process, will go on in the cells of the fruit, or all chemical change will be absolutely suspended. If the latter hypothesis should be realized the fruit would remain inert, intact, and we should there have an admirable means for the preservation of fruit. But that is not the case: experiment proves that it is the first hypothesis which is realized; the simplest observation shows that fruit plunged into an atmosphere of carbonic-acid gas is modified more or less profoundly. Plums, for example, become hard and woody, and the grape takes exactly the flavor of the vintage. Where, then, have the cells of the fruit, in order to accomplish this chemical work, which, like all other work, requires the consumption of heat—where, I repeat, have they found the heat needed for these modifications, for this sort of life continued under abnormal conditions? Certainly it does not come from combustion, due to free oxygen, as when the fruit is suspended in ordinary air, for in this atmosphere of carbonic-acid gas there is no free oxygen. This heat, indispensable to the phenomena which observation detects, is furnished by the decomposition of sugar. The position is the same as in the case of the decomposition of sugar in the presence of yeast-cells living without air. This decomposition of the sugar is manifested in the fruit by the production of alcohol and of carbonic acid. Here the ferment is the cell of the parenchyma of the fruit. There is in this cell a life kept up, or a chemical process accomplished, without air; according to our theory, fermentation should be present there, and experiment shows that it is. The theory, then, receives from this fact an extension and a generalization which increase and strengthen it.

That is why in my last communication to the Académie des Sciences I expressed myself thus: "Every being, every organ, every cell which has the faculty of accomplishing a chemical process with-

out using free oxygen gas, produces at once phenomena of fermentation."

I have not yet made the experiments, but every thing leads me to believe that animal cells should act like vegetable ones. Death cannot suppress instantly the reaction of the solids and liquids in the organism. I am convinced, but it is as yet only a preconceived idea, that on asphyxiating an animal suddenly there should appear here and there, and perhaps in all parts of his body, acts of fermentation whose slight duration or intensity have prevented their detection hitherto. Perhaps I may soon bring before this Academy the result of an experiment which would consist in tying firmly the limb of an animal so as to stop the circulation in it, and then plunging it into an atmosphere of carbonic-acid gas. What will take place in this limb thus stricken with death? A sort of physical and chemical life, if I may so speak, will continue and will probably manifest itself by phenomena of gangrene which I have long considered as having but distant connections with putrefaction, and which, in my opinion, might be classed with the phenomena offered by a fruit detached from the tree which bore it.

I shall now answer M. Bouillaud's question, "WHAT ARE THE FERMENTS OF THE FERMENTS?" In other words, "How can the ferments which are living beings, and which contain materials of the same order as those of all living beings, decompose after the decompositions which they have themselves provoked? How can they be destroyed and disappear, or at least be reduced to the germs alone, which are eternal, so much at least as life may be eternal on the surface of the earth? How can the materials which compose them become gaseous and return to the atmosphere in the more or less mineral forms of vapor, carbonic-acid gas, hydrogen, nitrogen, ammonia, etc.?"

Although in the transformations to which I allude, and which will now occupy us, Nature obeys a very small number of perfectly-determined general laws, the phenomena present an infinite variety in the details, and if I wished to include all the forms of the return to the air or soil of organic matter after death, it would require time and space which are not at my disposal; but as amid the thousand variations of the phenomena a very small number of laws preside over their manifestation, as these laws are found in all the individual cases, I cannot answer the question of our illustrious associate better than by taking a definite example, following it through all its phases, and then adding, "*ab uno disce omnes.*"

I shall take the return to the atmosphere, and to the soil, of one of the most precious fruits of the earth, the grape, and, far from restricting the difficulty, I shall take it in its greatest complexity. It is unnecessary to say that instead of the grape I might have taken any other woody or leafy organ, either of the vine or of any other plant,

and you will also understand that this example embraces the destruction of all the species by which life is manifested upon the face of the earth.

If I should describe the destruction of a single grape, abandoned to itself, I should show you only one of the laws of the phenomena; but there are two principal ones, and in order to pass them both in review I shall suppose that all the fruits of a vineyard have been gathered and placed in a gigantic heap, in an immense reservoir, as large as a mountain, if you choose. Under the influence of the weight the grapes are separated from the stems, broken more or less, and allow their contents to escape in the form of a sugary liquid. By a fortunate coincidence (which M. Colin might at his ease and by the aid of sentiment look upon as an express desire of Providence to furnish man what is called wine), it happens that at the period of the maturity of the grape its surface and that of the stems are covered here and there in the form of a fine dust by an extraordinary number of the germs of a small cellular plant which has the faculty, its germination once commenced, under the influence of a very small quantity of air, to multiply indefinitely in the entire absence of free oxygen gas—this was proved at our last meeting—and to provoke, correlatively with its life, the decomposition of sugar into carbonic-acid gas which is set free, and an alcohol which remains in solution in the liquid.

In the must of the grape the principal substance, after the water, is the sugar; it constitutes 20.25 parts in 100, sometimes even more; now, the decomposition accomplished by the ferment of which we have just spoken eliminates in the form of carbonic-acid gas more than half of this sugar, and thus a considerable portion of the organic matter of the grape returns to the atmosphere.

This singular phenomenon, which has struck the imagination of men ever since the beginning of the world, is accompanied by an intense heat and a bubbling of the whole mass, but as the sugar disappears the movement slowly ceases. As soon as quiet is restored, our immense cask is found to be filled with an alcoholic liquid which is the habitual drink of men living in southern countries. Scarcely has the carbonic-acid gas ceased to escape, when an attentive eye sees a pellicle form upon the surface, a pellicle which is extremely thin and insignificant in appearance, but in which reside a new life and new phenomena well worth our attention: this pellicle is formed of a mycodermic plant (of two, in fact, but for the sake of brevity I shall consider only one) which, strictly speaking, we might class with that one which has just flourished in our cask and decomposed the sugar, but which has now fallen inert to the bottom. Still, if our two little plants resemble one another in their anatomical structure, they are very different physiologically. The cells of the ferment which destroyed the sugar lived and multiplied without air; the new cells, on the other hand, spread over the surface of the liquid in an unbroken pellicle,

cannot live without the aid of the oxygen of the air. Furthermore, they fix this oxygen upon the alcohol contained in the wine according to the following equation: 46 parts, by weight, of alcohol unite with 32 parts of oxygen to form 60 parts of acetic acid and 18 parts of water. The combustion which results from the taking up of these 32 parts of oxygen is such that the whole surface of the liquid to a certain depth shows a temperature several degrees higher than that of the deeper portions; clouds of vapor rise above the cask, clouds formed mainly of steam, mingled with a few odorous products and some vapor of acetic acid. Little by little all these external phenomena diminish and finally cease entirely, and the mycodermic pellicle falls inert to join the preceding ferment at the bottom of the reservoir. And now instead of a reservoir of wine we have a reservoir of vinegar, in which our learned colleague may again see, at his leisure, and still sentimentally, a result of divine foresight, in the form of a final cause.

But let us continue. Our task—that is, the determination of the return of the organic matter to the atmosphere and to the soil—has been very little furthered by the second phase of the phenomena which we have just described; the alcohol, 100 parts of which contain more than 52 parts of carbon, more than 13 parts of hydrogen, and nearly 35 parts of oxygen, all coming from the original sugar, has indeed disappeared and given place to the acetic acid, but the matter has not become gaseous, it has not returned to the atmosphere as it partly did at the beginning. All the carbon of the alcohol has remained in the newly-formed acetic acid.

Notice what now takes place in our immense reservoir of vinegar, at the bottom of which lie heaped together the stems, the pellicle, the pits, the cells, the parenchyma of the fruit, and our two ferments, the wine-yeast and the vinegar-yeast. The quiet of which I spoke, and which was established a moment ago, has not lasted long: the ferment of the vinegar (and the fact is very curious) which has just fallen to the bottom of the cask, exhausted by the immense chemical work which it has produced, rendered inert by the sharp combustion of which it has been the seat, reappears, little by little, on the surface of our acid liquid, always in the form of a very thin pellicle; and, little by little, again the upper strata of the vinegar heat, and again clouds rise above the liquid. These clouds are no longer composed solely of the vapor of water; the latter is still very abundant in them, but it is mingled with torrents of carbonic-acid gas, and this remarkable phenomenon continues as long as any acetic acid remains in the liquid; in other words, after the vinegar ferment, an *aërobic* ferment—one needing air—has burned the alcohol and turned it into water and acetic acid, it burns the latter and turns it into water and carbonic acid. It also burns the original acids of the grape.

This time, that is, in the third phase of the phenomena, the return to the atmosphere has gone on rapidly: all the carbon, all the hydro-

gen, all the oxygen of the original sugar, are now in suspension in the air in the gaseous state, ready to be borne away by the winds and again to enter into the cycle of life under the influence of the beneficent heat of the sun. It is here that I would place the providential idea, not sentimentally only, this time, but by a real and serious scientific deduction, and because it seems to me that we have seized one of the great laws of Nature.

Let us return a little upon our steps and see where we are. What is the condition of our liquid mass? It is now only water holding in solution a very small quantity of mineral or organic substances. Evaporation would promptly reduce the whole mass to the deposit of which I spoke a moment ago, and which is lying at the bottom of the vessel, the wine-yeast, the vinegar-yeast in two portions, that which formed the vinegar and that which destroyed it, together with the stems and skins of the grapes.

What is going to take place in this liquid mass, no longer acid, but neutral now, in which there is held in solution only a little mineral and nitrogenized matter, which, it is true, is always ready to be renewed, at least for a long time, by the help of the materials at the bottom, which, thus far, have undergone nothing but simple maceration?

Pressed for time, I was only able at our last meeting to begin my answer to M. Bouillaud, and to do that even in terms so far removed from the subject that you must have found it difficult to understand the connection of the phenomena then described with the real object of the question. This connection, prepared by what has preceded, will now seem very clear.

Have we not reached a point in the succession of the grand natural phenomena which I am passing in review, at which we have to deal with a liquid of absolutely the same kind as that which I showed you at our last meeting, and one which is even more suitable for the phenomena of putrefaction of which I then spoke? If the liquid of our great reservoir is now formed of distilled water, phosphates, chlorides, and sulphates, there is at the bottom, to replace the lactate of lime of last Tuesday's experiment, a collection of carbonized or nitrogenized substances much better fitted than lactic acid to supply the carbonic food suitable for the development of the vibrios.

And, in fact, scarcely has the last mycodermic pellicle fallen to the bottom, scarcely have a new death and a new quiet fallen upon our liquid, scarcely has it lost all acidity, when, little by little, it becomes cloudy throughout; germs floating in the air have brought to it a new life, not one like those which you have seen precede it, but another, one rendered possible by the neutral character of the new liquid. The whole surface becomes covered by a layer of fatty, mucilaginous aspect. In the deeper portions, throughout the whole mass, as I said, we see a milky cloudiness; at the same time an infectious and very deleterious odor announces, even at a distance, the putrefaction and

the danger. It is thus that a part of the sulphur, phosphorus, and nitrogen of the sulphates, phosphates, and nitrogenized substances, return to the atmosphere in the form of gaseous products, but they will not long remain deleterious, for the oxygen of the air decomposes them incessantly, and transforms them into gaseous products useful to vegetation.

I spoke of a fatty, humid pellicle, formed on the surface, and of a milky cloudiness, occupying the whole mass: examine the pellicle under the microscope; the smallest fragment of it shows us millions of bacteria; below it, even in the deepest layers, a drop of the liquid presents the vibrios of putrefaction without a trace of bacteria. The bacteria are only on the surface, because they are *aërobic*, that is, they need air to live; the vibrios are below, because they do not need air to live, and, indeed, the layer of bacteria protects them against the approach of the oxygen gas which would be fatal to them if too much of it were held in solution by the liquid.

While the vibrios transform a large part of the solid materials macerating in our liquid into the gaseous products of putrefaction, the bacteria of the surface fix a considerable amount of the oxygen of the air upon the carbonic substances held in solution, and now again large quantities of carbonic-acid gas are set free. But, little by little, the medium which at first was so suitable for the nourishment of bacteria and vibrios becomes less so, a change which is announced, especially as to the bacteria, by a steadily-decreasing appropriation of the oxygen of the air; then appear, here and there, on the surface of the fatty pellicle, greenish, *glaucous* spots which increase as life becomes less active in the bacteria. These spots are spots of mould, new aërobic beings like the bacteria, and which find in the latter an appropriate food; little by little, the whole surface of the liquid will thus become covered by differently-colored moulds. Like the bacteria and the mycodermic pellicles, these moulds also cause much oxygen to combine with the subjacent substances which serve as their food, and again carbonic-acid gas is set free.

You see, then, that the substances dissolved in the liquid of our reservoir and deposited upon its bottom are constantly becoming gaseous and mineral. But during the continuance of all these phenomena, which last for months or for years according to the quantity of original material and the state of the atmosphere, an incessant evaporation, much increased by the heat of the successive combustions of which the surface of the liquid has been the theatre, has removed most of the water contained in the reservoir, and the latter dries, leaving on the bottom an insignificant quantity of each of the substances originally deposited there; but the combustions go on: here by the moulds, there by bacteria, monads, kolpods. When a mould has exhausted, if we may so call it, the appropriation for its life furnished by that portion of the surface or of the material upon which it has lived, it is replaced by an-

other to which, in turn, it serves as food. And observation shows that, so long as there remains any organic matter which can furnish carbon, the life of the moulds or of the infusoria is prolonged, but always with the result of setting free, in the form of carbonic acid-gas, a part of the carbon, while the life draws its other materials from the mineral salts and from the nitrogen of the ammonia compounds. The saline substances indeed are very abundant, for at no time have they been able to take on the gaseous form. And, finally, what remains? 1. Ashes, as if fire had been applied to the matter, for these slow successive combustions have produced the effect of fire; 2. The last germs of the last beings which lived upon the remains of their fellows. The mineral substances are ready to return to the soil, the organic matter has passed into the air, and when all shall have become dry the spores of the moulds and the cysts of the infusoria will be borne away upon the wings of the wind to recommence, elsewhere, their work of life and of destruction of life.

The ferments, and especially the aërobic ferments or the beings which are like them, are then the ferments of the ferments.

After the anaërobic ferments have commenced the disorganization of the material, the aërobic beings intervene and burn the organic matter as completely as it would be burned by fire—more slowly, it is true, but of what importance is time in the work of destruction by the life of germs?—for it is in them alone that resides the perpetuity of the life of microscopic beings.

CROLL ON CLIMATE AND TIME.[1]

By E. LEWIS, Jr.

THE distribution of temperatures upon the globe is a subject of profound popular and scientific interest. More than any other, it affects the distribution of living forms, not only in zones of climate, but in geological time. The contour of the earth's surface, and the relations of land and water upon it, may produce important local changes, or establish local faunas and floras, but these are scarcely more than modifications of grander and more general results. Arctic plants may, indeed, flourish under the equator, but only on mountains where an arctic climate prevails. Heat determines the limits equally of the vine, the palm of the tropics, the cereals of the temperate zone, and the food of the reindeer. Whether or not tree-ferns grow in Pennsylvania, and forests of pine in the Arctic Circle, depends on cli-

[1] Climate and Time in their Geological Relations: a Theory of Secular Changes of the Earth's Climate. By James Croll, of Her Majesty's Geological Survey of Scotland. New York: D. Appleton & Co. 1875

mate. Nor is this a phenomenon of the present age only. Geology proves from its records that, while a torrid zone may have existed since climates began, yet polar and temperate regions have witnessed changes both of climate and of life in wonderful succession, and in periods of immense duration. The causes which have contributed to these results have been sought and studied by some of the most eminent scientists of our time. Humboldt, Sir John Herschel, Sir William Thomson, Lieutenant Maury, Sir Charles Lyell, and more recently Dr. Carpenter and others, have investigated the subject in many of its aspects, and their conclusions are before the world; but no one, we believe, has presented it from so many points of view, or attacked its complex problems with greater vigor, than Mr. James Croll, whose volume is now before us. His conclusion is, that not only great secular changes of climate, but the distribution of temperatures upon the earth's surface at the present time, are due to causes which alter the volume, intensity, and direction, of the trade-winds and other prevailing winds of the globe. For the question at issue is not the amount of heat received upon the earth's surface, but the means by which it is distributed. It is not claimed that the great heat of the equatorial regions is carried directly to the polar regions by winds. That such a result is impossible is shown by the fact that the heated air rises at the equator, and moves toward the poles at an elevation where the temperature is at freezing, and its heat is lost or radiated into space.

But the prevailing winds, and mainly the trades, give rise to great surface-movements of the ocean, chief of which is the Gulf Stream. Here, however, the author enters on disputed ground. We have not space to follow him in his criticisms on Lieutenant Maury and Dr. Carpenter, each of whom attributes oceanic circulation to difference of specific gravity of the water rather than to winds.

It is evident, however, that the value of this question depends upon a previous one, What influence have ocean-currents on climate, and what is their capacity for the transference of heat? For clearness and brevity we will confine our inquiry to the North Atlantic and its great current, the Gulf Stream. By one of the lowest estimates made of the volume and velocity of this stream, there is conveyed by it not less than 2,787,840,000,000 cubic feet of water every hour. This is about 1,200 times as much as the average hourly discharge of the Mississippi. "No droughts affect it;" the flow is incessant, and the volume continues unchanged, save by causes which we will presently mention.

The mean temperature of this water as it emerges from the Gulf is about 65° Fahr. As the stream spreads over the North Atlantic its heat is imparted to the atmosphere, and diffused by winds. It is certain that the entire volume of Gulf-Stream water loses in this way 25° of its heat; and this represents its warming capacity. To this we refer the mild climate of England, of Norway, and Iceland. The heat thus

conveyed and distributed by each cubic foot of water is 1,158,000 foot-pounds,[1] and by the whole volume of Gulf-Stream water there is transferred every day from the equatorial regions 77,479,650,000,000,000,000 foot-pounds of heat. But these figures convey no definite impression of the vastness of the results. It is equal to one-fourth of all the heat received from the sun by the whole Atlantic Ocean from the Tropic of Cancer to the Arctic Circle, raising the temperature of its waters one-fifth—it is equal to about one-half the solar heat which falls upon the entire arctic regions. Under the equator there comes from the sun on each square foot of surface about 83 foot-pounds of heat every second, when the sun is in the zenith. Twenty-two per cent. of this is absorbed by the atmosphere; the remainder falls as heating-power upon the ocean. Now, the quantity conveyed is equal to all that thus falls upon 1,560,935 square miles of surface. If this source of heat be destroyed or turned away, the area of arctic winter would rapidly extend southward, covering England, both Old and New, with ice which the heat of summer would not remove.

Nor would any conceivable movements of the atmosphere supply the deficiency of heat. For not only does heated air at the equator rise, and radiate its heat in the cold regions of the upper atmosphere, but the capacity of air for heat is much less than water. So great is the difference in this respect that the Gulf Stream conveys as much heat as a current of air would if 3,234 times as large, of the same temperature, and moving with the same velocity. The heated air, however, which rises at the equator is charged with vapor, and in the opinion of Sir John Herschel this vapor, conveyed by the upper or anti-trades, is condensed in the temperate and arctic regions, greatly modifying their temperature. To the extent that the vapors are thus conveyed, the conclusion of Sir John is correct; for, as Prof. Tyndall has shown, in the conversion of one pound of aqueous vapor into water there is given out as much heat as is sufficient to melt five pounds of cast-iron. But Mr. Croll proves that the greater part of the vapor raised in the equatorial regions falls there as rain; that the upper winds are dry, and gather moisture only when they again reach the earth and become surface-winds in the temperate and arctic zones.

If all currents of the ocean and atmosphere should cease, no heat could be transferred from the equatorial to the arctic regions, and temperatures would depend on the solar heat falling in the respective latitudes. The equatorial and arctic regions would become uninhabitable, the mean temperatures rising to 135° Fahr. in the one, and sinking to 83° below zero in the other. The present difference of 80° would be increased to 218°, and only a narrow zone of temperate climate would prevail.

[1] A foot-pound is the amount of heat-force expended in raising one pound one foot; 772 foot-pounds is the equivalent of the heat that will raise one pound of water one degree of temperature.

Dr. Franklin suggested that the Gulf Stream has its origin in the trade-winds. It was a crude but sagacious remark. Lieutenant Maury, however, thought the cause wholly inadequate, and that the phenomenon is better explained by difference in the density and specific gravity of ocean-waters, arising mainly from differences of temperature. Dr. Carpenter, too, insists on difference in specific gravity as a cause of ocean circulation, but claims that the circulation is a diffused or general one of the ocean-waters between poles and equator, and attaches comparatively little importance to the Gulf Stream. Mr. Croll, however, revives the views of Dr. Franklin with surprising ability, and finds in the great wind-currents, and chiefly in the trade-winds, a cause adequate to the result. The wind and ocean currents coincide all over the globe. The waters move with the general set of the trade-winds—the direction of the one is a reliable exponent of the set of the other.

Now, it is obvious that any influence which changes the direction of the winds will also affect that of the currents, and in that way the climates of the globe.

At present the equatorial waters heated by the sun to a temperature of 83° move westward between the tropics at the rate of thirty miles in twenty-four hours. This is called the equatorial current. It impinges upon the coast of South America, a small portion going southward, the principal portion northward, and is discharged as the Gulf Stream. It is deflected every year by changes in the trade-winds; it is thrown northward when the southeast trade is at its maximum. We will confine our attention now to the northeast trades. Should these be increased in velocity and volume, they would also assume a somewhat more northerly direction at the equator, carrying the equatorial current southward beyond the median line, and increasing the volume of the southern at the expense of the northern flow. From this cause the temperature of the Northern Hemisphere would be greatly lowered, while the mildness of summer would prevail in the Southern Hemisphere.

Causes, therefore, which alter the force and direction of the trades are adequate to change the climates of the globe, and in the opinion of Mr. Croll these causes are found in variations in the earth's path around the sun, combined with the precession of the equinoxes. These affect not, indeed, the total volume of heat received by the earth in a year, but the distribution of it by the means already referred to. If it happen that during a vast period of time the winters of our Northern Hemisphere should occur when the earth is farthest from the sun, and its orbit at its greatest eccentricity, the result would be winters long and cold, with summers short but hot. The earth would in that case be 8,641,870 miles farther from the sun in winter than at present, and during that season would receive one-fifth less direct heat from it. At present the winters are eight days shorter than the summers, but

in the conditions referred to the winters would exceed the summers by thirty-six days.

It is not claimed by Mr. Croll that a cold or glacial epoch is directly caused by the increased distance of the earth from the sun, but from physical agents thus brought into operation. Some of these we will proceed to mention.

As the winters increase in length, and the cold in intensity, the volume of snow-fall will become greater, and its area extended. The limit at which the summer sun melts it will move slowly southward. Behind it will be a gradual accumulation of snow forming into ice. Mountain-slopes will be covered with it, until it flows down into valleys and onward, a vast sheet of glacial ice, equally on lowlands and mountains.

Out of this condition will arise several results which powerfully react, increasing and intensifying the cold of the growing winter. A volume of snow and ice covering the ground chills the air by direct radiation, and by contact lowers its general temperature, thus delaying or arresting the process of melting by the summer's sun. It is a familiar fact that in snow-covered regions the direct rays of the sun may be intensely hot, melting pitch from timber, or heating rocks, while the temperature of the air is that of the ice upon the ground. The regions of Hudson Bay are sterile, not because the heat from the summer sun is not intense, but because they are covered with ice all the year. But for this the climate might be as genial as that of England. Ice and snow maintain steadily a temperature ot 32°, no matter how hot the sun's rays may be, and a rock or piece of earth will become greatly heated, while a block of ice consumes the heat that falls upon it. The solar heat is, therefore, expended in breaking down the molecular structure of the ice, and must continue to do so until it disappears. By as much heat as is used over a region in this way is the heating effect of the sun's rays diminished, and a low atmospheric temperature is the result.

But the sun's rays falling on snow are to a considerable extent reflected back into space from its innumerable surfaces, greatly decreasing their heating effect.

The snow-sheet exerts another important influence on temperature by condensing the vapor of the air into fogs as the summers come on. In this way the solar rays are arrested, and their heating power dissipated. This occurs continually during the summers of arctic and antarctic regions. Dr. Scoresby observes in regard to the arctic regions that "the sun, when near the northern tropic, gives scarcely any sensible quantity of light from noon till midnight; it is frequently invisible for several successive days, and snow is so common that it may be boldly stated that it falls nine days out of ten from April to July." These are the conditions of climate in which glaciers grow and throw abroad their chilling influence. We are now to consider

their relations to the atmosphere and ocean in respect to their movements. The trade-winds owe their existence to the difference of temperature between the equator and the poles. Whatever increases this difference increases the strength and volume of the winds, whether in the Northern or Southern Hemisphere. The coming on of a period of northern glacial cold would be concurrent with increasing violence of the northeast trade-wind. It would sweep at its maximum far beyond the equator, for the Southern Hemisphere would be heated and the line of greatest equatorial heat would be southward from its present position. A deflection of the great equatorial current of the ocean would occur corresponding with this, and its vast volume of heated waters would pour into the southern instead of into the northern ocean. The Gulf Stream would cease to flow, or flow only with greatly diminished volume. "In the severest droughts it never fails," said Prof. Maury, but it may fail from other causes, and leave half a hemisphere rigid from the austerity of cold. Depleted of the Gulf Stream, the surface-waters of the North Atlantic would be warmed only by the direct rays of the sun, and would rapidly approximate to the low temperatures which now prevail only a few fathoms beneath the surface. The mean temperature of Scotland for January is 28° higher than its normal, and 15° above its normal for the year. The loss of the Gulf Stream would change all this.

Theories which have made the Ice period depend wholly on cold are shown to be untenable by Prof. Tyndall, who calls attention to the fact that great heat is as necessary to the production and growth of glaciers as intense cold, the one being needed to produce vapor, the other to condense and freeze it. Any accumulation of snow and glacial ice is impossible without this combination of circumstances; but these constitute an integral part of Mr. Croll's theory, which assigns a mild climate to one hemisphere while the other is wrapped with ice.

Alternation of climates in geological time is as certain as diversity of climate at the present day. Evidence of it is found in the geological record, and eras of glaciation have succeeded each other, but each one has buried or erased many traces of preceding ones, and only the last one is before us, the monumental history of which reveals its startling and wonderful features.

It is held indeed by Mr. Croll that eras of cold and glaciers alternating with those of temperate climate are fully accounted for by the causes stated. His conclusions, however, are not accepted by many eminent geologists. Prof. Dana says that climatic changes effected by the Gulf Stream have been brought about, "not by diversions of the current from the ocean, and its restoration to it again, but by variations in the amount and height of arctic lands, in one case closing and the other opening the arctic regions to the tropical stream, and the same for the Pacific current." While this view may not call in question the warming influences of the stream, it assigns

other reasons than those given by Mr. Croll why its effects may be greatly varied. Nor can there be any doubt that changes in the general level of the land, altering coast-lines and the currents of both the atmosphere and the ocean, are important agents in modifying temperatures. We cannot follow into details Mr. Croll's exhaustive inquiries, but our readers will be interested in his answer to the well-known theory of Sir Charles Lyell. According to that eminent authority, a period of polar cold will result from a great increase of elevation and extent of land in polar regions, and a warm period in the polar zones will occur by a great accession of land in the equatorial regions. But Mr. Croll shows that such changes in the distribution of land would be followed by opposite results—that a great accession of land in the equatorial zone would destroy the system of ocean-circulation by which the heat of the equator is made to do service in warming the ocean and the air of colder zones.

In Mr. Croll's theory it is impossible that both hemispheres should be glaciated at the same time. Not only must periods of heat alternate with those of cold in one hemisphere, but a glacial epoch in one is accompanied by a temperate epoch in the other.

It is evident that changes of climate such as are shown to have occurred must have arisen from general, not from any local cause or accidental combination of causes, and if this be so there may yet appear a reliable means of determining not only the amount and extent of the changes, but the periods of their duration and recurrence. The question of time in geological history is an important and certainly a most interesting one, and the interest in it has increased since the announcement by Dr. Tiddeman and others that human relics have been found in deposits of the warm inter-glacial periods.

Two methods have been adopted by Mr. Croll which are supposed to throw light on this subject. One is to fix the period and duration of the epochs of greatest heat and cold by computing the period and duration of the astronomical coincidences already noticed, by which according to his theory those epochs were brought about. The other method is applied to estimating the time since the close of the last glacial epoch by changes known to have taken place in the earth's surface, and the general lowering of the land by denudation. To do this, he says, "we have only to ascertain the quantity of sediment annually carried down by the river systems."

By this means it is found that the lowering may have been nearly a foot in 6,000 years. But when we consider how greatly the general result may have been interfered with by the alternate elevation and depression of the land, a work now going on, we realize that Mr. Croll's conclusions do little more than profoundly impress the mind with the vastness of time required in some of the most obvious of Nature's operations.

By the first-named method computations have been made extending

back three millions and forward one million of years. But we believe that most geologists agree with the statement of Sir Charles Lyell that "an attempt to assign chronological value to any except the latest geological epochs must in the present state of science be hopeless."

It may be stated, however, that during the period covered by the computations, three epochs of greatest eccentricity of the earth's orbit occurred, and in each of these it is found that the eccentricity is not uniform, but rises and falls. Hence the coming on and departure of each period may have been continuous, but by no means regular. Sometimes the changes were at the comparatively short intervals of 10,000 or 12,000 years, and the close relation these changes may have had to the life of the time, possibly to extinction of species, is plausibly suggested by Mr. Croll.

The period of great eccentricity to which the last glacial epoch is referred began about 240,000 years ago, and extended over a period of about 160,000 years. The conclusion, therefore, is that it closed about 80,000 years ago. It is not easy to understand, however, what value to attach to the words "close of the glacial epoch." Shall we say that it closed when the ice ceased to exist as a glacier along the shores of New England, or when it extended no farther southward than the Canadian highlands? The gigantic fields of ice which now cover both arctic and antarctic lands prove that, within areas more limited indeed than in former time, the glacial epoch still exists in its stern and sublime reality.

Whether we consider the facts of geology or those of astronomical computation, it seems evident that the growth and decline of the ice-sheet, and of the causes which produced it, have been in no sense cataclysmic or accidental, but secular; only after ages have passed are we enabled to realize, from the altered aspects of Nature, that a great change is in progress. At present the eccentricity of the earth's orbit is diminishing. In a little less than 24,000 years it will be "as nearly circular as it can ever be;" and if Mr. Croll's tables are to be relied on, no cycles of extreme heat or cold will occur for the next 150,000 years. We are entering a period of comparatively equable climate, arising from a more uniform distribution of solar heat over the surface of the globe.

THE ARTIFICIAL PREPARATION OF ORGANIC BODIES.

By IRA REMSEN,
PROFESSOR OF CHEMISTRY IN WILLIAMS COLLEGE.

THE "good, old" foundation upon which our fathers stood has been sadly shaken. Its complete overthrow has at times seemed inevitable. "Scientific men" have led the attacking army, and thus gradually brought themselves into disgrace with a portion of the

community. The fight has been carried on to a great extent blindly, and most attempts to establish order have only succeeded in increasing the confusion. Sorties from the camp of "the fathers" have been made, and weapons have been carried back; but, alas! the weapons were useless, or, if used, they injured the user. The conflict is still waging, and it will continue to wage. Occasionally faint promises of a better understanding are given, but some misguided enthusiast, on one side or the other, hastens to destroy the hopes of a happy issue. The frequent shocks received by "the fathers" have unduly excited them, and they look upon each advance of science as something dangerous. Often they do not stop to examine whether the movement of the hostile party is, or is not, antagonistic to their position, but blindly throw their whole force against it, and anxiously look for the results of the crash. It sometimes happens that they thus waste their force, and weaken themselves for future necessary encounters.

Dropping the figure, we may safely assert that those who are avowedly the opponents of science, though their objects may be the highest—though they may be actuated by only noble desires—have, unfortunately, from time to time brought ridicule upon themselves by upholding views which were not tenable, and which a careful examination and thorough knowledge of the subject would show to be unnecessary for the support of their theories. These somewhat trite remarks lead to a consideration of the subject embraced in the title of this paper.

There are certain chemical substances known to us which only occur in the organs of plants or animals. The number of these substances at present known is very great, and new ones are being rapidly added to the list. They consist often of but three elements—carbon, oxygen, and hydrogen; sometimes nitrogen is added to these, and, rarely, phosphorus or sulphur. Notwithstanding the fact that they are made up of few constituents, they are usually of complicated structure; indeed, the complication in some of them is so great that, with our present means of analysis, we are unable to express their composition by means of satisfactory formulæ. The substances referred to have been known by the name *organic bodies.*

Up to within a few years chemists were, to a certain extent, justified in drawing a line of division between two classes of bodies, both occurring in Nature: 1. Those which can be prepared in the laboratory; 2. Those which cannot be prepared in the laboratory. The second class included the so-called organic bodies. These were known to occur only in the organs of plants or animals. The two facts, taken together, were significant, and but little surprise can be expressed that a connection was traced between them. The simplest conclusion that could be drawn from the premises *was* drawn, and the scientific world, buoyed up by certain preconceived notions in regard

to life, tacitly accepted it. Chemical substances which are produced under the mysterious influence of life, in the dark, unfathomed cavities of living organisms, cannot be produced by the hand of the mortal chemist. This was the conclusion which grew to be a dogma, and was used as a kind of *ex post facto* argument in favor of certain views in regard to the so-called "vital force."

But its influence did not cease here. Having worked so beneficially as an important link in a chain of retrograde logical sequences, it was afterward made a starting-point for other lines of argument. It was employed in religious and purely philosophical discussions, and assisted in the establishment of subsequent illogical conclusions.

As these discussions were taking place, the chemist quietly continued his strange dealings with the elements. Discovery followed discovery, until the fact could no longer be doubted that the dogma must fall. Its fall was, however, not the matter of a moment. It received repeated blows before it gave up its existence. Its place has been taken by an hypothetical statement founded upon a large array of facts, viz.: every chemical body, no matter of how complicated a structure, or what its nature may be, will probably, in good time, be prepared artificially in the chemist's laboratory. And this statement becomes more and more probable every day. Already a large number of the compounds, the formation of which was formerly supposed to be dependent upon the action of the vital force, have been reproduced entirely independently of any suspicion of the action of this force; and thousands of other analogous compounds which have never been found in plant nor animal are now known to us. Let us look briefly at some of the steps that were taken in this advance of opinion.

In the year 1828 Wöhler made the first observation bearing directly upon this subject. A few years earlier he had discovered cyanic acid, and he was now engaged in the thorough investigation of this acid. He prepared its ammonium salt, and, on evaporating the aqueous solution of the salt, he noticed the formation of large, well-developed crystals that in every respect resembled *urea*. Urea was well known, but had, up to that time, only been found among the products formed in animal bodies. Its existence was, in accordance with the then prevalent views, supposed to be due to the inexplicable action of the vital force. A careful examination failed to disclose any points of difference between the two bodies, and Wöhler was forced to the conclusion that at least one organic substance could be prepared outside of the organism.

But this by no means brought about a change of views. The upholders of the old dogma immediately found relief which was apparently satisfactory. Cyanogen compounds, of course including cyanic acid, had only been prepared from substances which had had their origin in the organs of animals, and, although these original

substances had been subjected to purely chemical influences, and thus another animal substance produced, the vital force had nevertheless played its part as an essential agent in the formative process. This argument seemed plausible, and could hardly be objected to. Other and more decisive experiments were necessary.

In 1841 Fownes succeeded for the first time in preparing cyanogen directly from its elements. He passed nitrogen-gas over a mixture of charcoal and hydrate or carbonate of potassium at a red heat, and obtained a salt of cyanogen and potassium—cyanide of potassium. From this salt it was a comparatively simple matter to prepare all the other cyanogen compounds, and, finally, urea. Thus, then, there could be no doubt that a direct construction of some organic bodies from their elements was possible.

But urea, in comparison with most animal or vegetable products, is of simple structure. It contains but one atom of carbon in each molecule, whereas many others contain a very large number of carbon-atoms. The transformation of cyanate of ammonia into urea, which took place so readily, was a very simple one, if we consider merely the relation of the two bodies to each other. They have exactly the same composition. They contain the same percentages of carbon, hydrogen, nitrogen, and oxygen. A change of the arrangement of the atoms was necessary, but this was all—no addition of material, no building up, no binding together of a large number of atoms into one compound. There was still left something which could be ascribed to the influence of vital force, and this fact was seized upon and made to do service. It was now stated that, although it might be possible to prepare artificially some of the simpler organic bodies, the vital force was necessary to bring about the complicated form of union found in the greater number of the products of the life-process. This statement held its own for a number of years. In the mean time a series of brilliant experiments by Berthelot had established the fact that a large number of organic bodies could with ease be prepared artificially. In 1856 this chemist published the first results of his investigations. He had effected a direct union of carbonic oxide with hydrate of potassium, and thus obtained the potassium salt of formic acid. Later he showed that a direct union of carbon with hydrogen was possible; using carbon-poles, he passed a current of electricity through them in an atmosphere of hydrogen; he thus obtained acetylene, a hydrocarbon made up of two atoms of carbon and two of hydrogen. He also produced marsh-gas, ethylene, and a number of other hydrocarbons from inorganic materials which, in their turn, could be obtained from the elements. It was shown that marsh-gas could be converted into methyl alcohol; ethylene into ethyl alcohol; and from these alcohols it was an easy step to formic and acetic acid; to the aldehydes, amines, acetines, etc., etc. These results, although startling when viewed from the oldest stand-point,

could still be reconciled to these views as necessarily modified subsequently to Wöhler's discovery. The compounds thus formed artificially were still of comparatively simple structure; and, in the numerous transformations effected by Berthelot, in no case was the passage from a compound of a lower to one of a higher order. Marsh-gas, methyl alcohol, and formic acid, each contained but one atom of carbon; ethylene, ethyl alcohol, and acetic acid, each contained two atoms of carbon. Surely the vital force alone could build up more complicated bodies.

Not so. The series of advances in the new doctrine, thus so propitiously begun, did not stop. New methods of investigation were introduced. Questions of a different character were put to chemical substances, and answers were not wanting. The interest in chemical science increased, and the army of those who were to carry it forward also increased. The growth of the science became proverbially rapid, and, during the excitement attendant upon this development, the last of the old landmarks between inorganic and organic bodies was swept away; vital force, as far as it was directly concerned in the formation of organic bodies, lost prestige. Both classes of bodies were found to be subject to the same fixed laws. A chemical substance is a chemical substance, look at it as we will. Its constituents, in one case as in the other, are bound together by chemical affinity, simply and alone. Whatever the conditions may be which surround the formation of organic bodies in the animal or vegetable organism, the final combination of the atoms, necessary to the formation, is brought about by chemical affinity. Although we cannot reproduce these conditions outside of the body, we can in so far imitate them that the same kind of combination will take place. We have at our command at present many means for the building up of the most complicated organic bodies from the simplest. Some of these are easily understood, and were discovered as the result of strict logical deduction; others are still inexplicable, and were discovered by accident. We can pass readily from one hydrocarbon to another, adding carbon-atoms to an extent which, theoretically at least, is unlimited; from one acid to another of higher order; from alcohol to alcohol; from alcohol to acid; from acid to hydrocarbon; from hydrocarbon to acid, through all the normal series of organic compounds. So great is our power in this direction, that it is possible to produce any member of any regular series of organic compounds from marsh-gas as a starting-point, or from any other member whatsoever. But marsh-gas can be indirectly produced from its elements, carbon and hydrogen; hence, we have the possibility given of preparing artificially by far the greater number of organic compounds. This number includes many of those substances which are formed in the animal or vegetable organism.

The formation of urea and formic acid has been alluded to. With-

out reference to the historical order, a few of the achievements of chemists, which have from time to time astonished and delighted the world, may here be briefly noted. Among vegetable products are oxalic acid, which was formed directly from carbonic acid, a combination of two carbon-atoms being necessary in the process; valeric acid, containing five carbon-atoms; malic acid, with four carbon-atoms, one of the most widely-distributed acids of the vegetable kingdom, being contained in a large number of unripe fruits; cinnamic acid, containing nine atoms of carbon; tartaric acid, the acid of grape-juice. Wintergreen oil, obtained from *Gaultheria procumbens*, has been found to consist mainly of an organic ether, which can be, and has been, prepared artificially. The oil of garlic (*Allium sativum*) contains carbon, hydrogen, and sulphur. It can be prepared with all its properties without the plant. The oil of mustard, with its peculiar arrangement of carbon, hydrogen, nitrogen, and sulphur, is now manufactured on the large scale by a patented process, the mustard-plant being outrivaled by the chemist. The deadly poison conine, and the beautiful colors alizarine and indigo, finally, belong in the same list. In regard to alizarine or Turkey-red, it may be remarked that the discovery of the methods for its artificial preparation has led to the establishment of an important branch of industry of far-reaching influence. It is doubtful, however, whether as much will ever be said concerning the preparation of indigo. Among animal products that have yielded up the secrets of their internal structure to the chemist are the simple fats and the lactic acids. In a great many portions of the animal organism, as the brain, pancreas, liver, lungs, the thyroid and thymoid glands, is found a substance, containing six atoms of carbon, which has been called leucine. This substance is also a frequent product of the decomposition of organic bodies. Leucine is obtained more readily by artificial means than it can be extracted from the tissues in which it exists ready formed. A constant ingredient of the juice of flesh is creatine; and one of the products of decomposition of creatine is sarcosine. Both creatine and sarcosine can be constructed from the elements by purely chemical processes. Taurine, which occurs in the bile, in the contents of the alimentary canal, in the lung-tissue and the kidneys, and contains carbon, hydrogen, nitrogen, oxygen, and sulphur, can be prepared by a very simple process.

These examples suffice to indicate the character of the results already achieved, and furnish justification for the hope now entertained by chemists that in good time it will be possible to produce all chemical substances in the laboratory. No one who has given the subject a sufficient amount of attention to enable him to form an opinion can for a moment feel a doubt on this subject.

The old dogma no longer exists. There are those who sigh at its death; who consider that the sacrilegious step of Science which annihilated it has, in some way, tended to lessen the mystery of life, and

to embolden the votaries of science to look for, work for, further disclosures which may threaten some favorite view—it may be one of more importance than that which we have considered. But others, supporting themselves on the basis that truth can never be dangerous to the right, see no cause for alarm in such advances. They hail them with pleasure, and encourage the spirit which hastens their arrival. In regard to the special question treated in this paper, arguments are hardly necessary to show that the results of investigation, as we have stated them, could not materially modify any time-honored, fundamental views. Is life less of a mystery? Has the question concerning the nature of life been even approached in these researches? We think not. That chemical substances of peculiar structure are found in the living organism is true. That these substances are formed by the action of the force called chemical affinity is just as surely a truth. Do these two truths mutually detract from the importance of each other? When the active agent in the formation of the so-called organic bodies became known, a thousand questions could be proposed to one that could be proposed previously. The conditions for its working became subjects of inquiry, and an almost endless series of possibilities presented itself. From what substances have the new ones been formed? What chemical processes have brought about the final formation? Years—ages must elapse before our knowledge on these points can begin to be exhaustive. And then what? Is the mystery solved? No.

We are ascending a mountain of great light. Our views are becoming more and more extended as we reach higher and higher positions. Should we ever be enabled to reach the summit, there would be found a pleasant harmony in the broad panorama, and our eyes would rest in delight upon it; but the most extensive view has its horizon, the barrier between the visible and the invisible.

EARTHQUAKES AND THEIR CAUSES.

By JOHN J. LAKE.

THE origin of earthquakes has been assigned to many causes, as the falling in of caverns, steam, the combustion of gases, volcanic and electric action. Their most prominent and peculiar features are the following:

1. Great subterranean noises and reports resembling thunder. These occur more or less during all earthquakes. Father Kircher describes them as "a horrid sound resembling that of an infinite number of chariots driven fiercely forward, the wheels rattling, and the thongs of the whips cracking;" Sir Hans Sloane, in Jamaica, as

"a hollow rumbling noise almost like that of thunder." At Colares, near Lisbon, in 1755, during the great earthquake, the sound is said to have been "like that of chariots, which increased till it equaled that of the roar of cannon;" and at Lisbon, "a rattling as of coaches in the street, with a frightful noise underground resembling the rumbling of distant thunder." At Madeira the same earthquake was preceded "by rumbling noises in the air like that of empty carriages, which died away like a peal of distant thunder." On the 16th of September, 1849, there was an earthquake at Burra-Burra, in South Australia, where the noise is said to have resembled the rolling of heavy carriages. The shock was followed by a flash of lightning that illumined the whole atmosphere.

2. Another feature of these phenomena is the upheaval of the ground observed during the prevalence of most earthquakes, which is one cause of the sea retiring, another being the suction of the approaching wave when the centre of the convulsion has been removed from the shore. During the great earthquake at Lisbon the bar at the mouth of the Tagus was laid bare by the upheaval, and the master of a vessel, lying in that river at the time, stated that his large anchor was thrown up from the bottom, and seemed to swim on the surface of the water. Other results of the upward movement during this catastrophe were observed elsewhere. The water in a pond at Dunstal, in Suffolk, was jerked up into the form of a pyramid. At some places the water was tossed out of the wells. At Loch Lomond a large stone was forced out of the water. Rocks were raised into the air from the bottom of the Atlantic, and on board a vessel, about forty leagues from the island of St. Vincent in the West Indies, the anchors, which were lashed, bounced up, and the sailors thrown a foot and a half perpendicular from the deck, the ship sinking into the water immediately afterward as low as the main-chains. At Riobamba, in South America, on the 5th of January, 1797, the bodies of many of the inhabitants were thrown, by this vertical action, upon the hill of La Cullca, which is several hundred feet high, and on the opposite side of the river. During some of these convulsions in Italy, paving-stones have been tossed into the air and found with their lower sides uppermost; and, at the time of a late convulsion in South America, the rising of the ground caused the sea to retire, which returned like a wall in appearance, carrying before it inland vessels that had only a few minutes before been left dry, towns and people being overwhelmed by the resistless recoil.

3. Another peculiarity to be noticed in these convulsions is the frequent horizontal and circular motion of the soil. These effects are often very curious, and, in countries much subject to such catastrophes in their severest forms, have often given rise to lawsuits. Walls that had served to divide fields have been completely changed in direction, but without having been shattered or overthrown. Straight and par-

allel rows of trees have been inflected, and fields and portions of fields have changed places. Houses have also exchanged situations with each other.

4. It has been observed that clouds have become fixed or suspended over particular spots affected, or about to be affected, by earthquake, as in London, in 1749, in Calabria, in 1783; and it is more than probable that the fog that enveloped Euphemia, in Sicily, in 1638, Millitello in 1693, and other places when they were destroyed, arose from the operation of one cause.

5. Explosions of great violence frequently attend these convulsions, often with disastrous results. When Millitello was destroyed, there was a great explosion heard in the fog that enveloped it; traces were noticed afterward as of the presence of fire on the rocks in the neighborhood, and the vines in the country surrounding it appeared as though they had been seared by fire. A similar explosion was heard in 1783 at Castel Nuovo, in Calabria, when that place was overwhelmed.

6. A further peculiarity is the exemption of certain spots, although the shocks were felt in all the surrounding neighborhood. Thus, at Manchester, in 1777, St. Paul's Church and the Dissenting Chapel escaped. Both of these were low buildings without steeples, and the church situated over a common sewer; but other more lofty buildings, especially those with metal pipes attached, felt the shocks severely. At Blockley the shocks were experienced strongly at the church, but very slightly at the chapel about 300 yards distant, and the latter was constructed without water-pipes.

7. Earthquakes are very frequently attended by thunder and lightning. At Munster, in 1612, thunder and lightning were heavy during an earthquake; and in Sicily, in 1693, it caused very great mischief. This conjunction of lightning with earthquake was noticed by Luke Howard, and constitutes what he designates "spurious earthquake." One of the cases he mentions occured in Radnorshire: "At Knill Court the oscillation of the house was plainly perceptible, and felt by all the family, and that, too, in several apartments, and was accompanied by a peculiar rumbling noise. At Harpton, a severe storm of thunder and lightning was experienced the same night and at the same time."

8. Peculiar rushing noises have also at times been perceived, as in Staffordshire in 1692, and London in 1749.

9. These convulsions are attended by the disturbance of the magnetic needle, and compasses on board ship are frequently for a time useless. On the 19th of January, 1845, on the Thames steamer, during an earthquake in the West Indies, they revolved on their pivots with great rapidity; and on the 29th of October, 1867, during a hurricane, there were shocks of earthquake at St. Thomas's, and the electrical disturbance was so great as temporarily to render the compasses unavailable.

Such being some of the more prominent peculiarities attending earthquakes, let us now apply them to the theories above referred to, and endeavor to ascertain the causes of these disturbances or the agencies employed in producing them.

They do not support the theory of the falling in of caverns being the cause of these phenomena; for they are invariably attended by an upheaval of the ground, and often with a horizontal or a circular motion. This theory, therefore, cannot be maintained, and more especially as it does not explain the electric and magnetic accompaniments.

The hypothesis that they are caused by steam or the explosion of confined gases has scarcely a better foundation. These agents might produce vertical motion and subterranean noises, but it is difficult to conceive how they could bring about circular motion at the surface; and it is quite impossible that the explosion of gases or the escape of steam could, immediately preceding a shock, attract the clouds floating in the atmosphere, so that they should remain fixed over particular spots. Other characteristics also cannot be explained on this theory, as the lightning and disturbance of the compass.

The volcanic and igneous theory is not so easily to be disposed of; for it appears very clear that volcanic eruptions do produce earthquake. A remarkable instance is that of Santorini in 1650. Earthquake is also very common where volcanic action is extensively developed, as in South America and the neighborhood of Etna and Vesuvius.

Volcanoes produce these disturbances in two ways: 1. By their own direct motion; 2. By disturbing the electric equilibrium in their neighborhood. This electric disturbance was noticed by Pliny, who records that an officer, one of the Decuriones Municipales of Pompeii, was struck by lightning in 79, although the sky was perfectly unclouded; and these indications have been put to practical use. The presence of lightning is also a prominent feature during volcanic eruptions. When Kattleguia, in Iceland, now extinct, was last in a state of eruption, lightning proceeded from it and killed a farmer and his servant, together with some horses and cows. We cannot, therefore, exclude the consideration of volcanoes as producers of earthquake, sometimes by direct action, at others through the medium of electric disturbance.

But by far the most prominent agent seems to be electricity, and the Italians, who suffer so much from these calamities, consider it to be the only cause. The evidences of the activity of the electric fluid in this respect are so palpable that they cannot be controverted. As some may be skeptical on this point, it will not be amiss to examine a few cases in which the operation of this agent is quite apparent.

When considering this part of the subject, we must not omit to notice the frequency with which the greatest weight of these calami-

ties falls upon towns and the neighborhoods of mountains. This is to be accounted for on the electric theory, from these places offering points for the escape of the fluid which naturally flies there to seek a thoroughfare, so to speak. From this cause we have St. Elmo's fire on the masts and yards of ships at sea, and De Saussure's experiences of the escape of the fluid from an Alpine peak. Hence we may infer that towns and mountains create centres of force in these convulsions.

At Münster, in Germany, an earthquake began on December 8, 1612, and lasted for several days. During the shocks, Billenelt Castle, near Münster, built on a rock, "sunk more than the depth of two men's height," a breach being made in the rock itself. The destruction by earthquake and lightning seems to have been great. "If any," says a chronicler of the catastrophe, "have so much heart left as to lift up his hands to heaven, he is presently struck down by thunder and lightning;" "fiery clouds and a direful comet" alarmed the superstitious. The state of the atmosphere must have been very peculiar, even allowing for exaggeration, since the writer referred to states that the appearance of the stars was "changed into prodigious, dreadful, fiery meteors." During this calamity, earthquake, thunder, and lightning, occurred twice every day, but not at the same time.

The earthquake of 1638 disturbed both Etna and Stromboli, causing them to send forth flame and smoke, as though the sources of the convulsion descended deeper than their roots. Father Kircher describes the disappearance of the city of Euphemia, which he was endeavoring to reach at this time, and was in sight of. After a violent shock, on rising from the ground and looking toward the city, he saw only a frightful dark cloud, which surprised him and his companions, as the sky was otherwise very serene. Waiting until the cloud had passed away, they found Euphemia had totally disappeared, and its place a putrid lake.

The earthquakes of 1692, in Jamaica, and 1693, in Sicily, present very strong evidences of general electric disturbance in the globe at those times. One evening in February, 1692, at Alari, in Sicily, the village seemed to the country-people to be in flames. The fire, as they imagined, began by little and increased for about a quarter of an hour, when all the houses in the place appeared to be enveloped in one flame which lasted about six minutes and then began to decay, as from want of more fuel. Many who ran to render assistance observed this increase as they passed along the road, but on entering the village found all to be a delusion. Such appearances of fire and light occur in other localities subject to earthquake, e. g., at Cowrie, Perthshire, one morning before daybreak, in 1842, the light is stated to have been so brilliant that birds were distinguished on the trees. Again, in Sicily, about the 15th of May, following the incident at Alari, two hours before sunset, the atmosphere being very clear, the heavens appeared on a sudden all on fire, without any flashes of lightning or the

least noise of thunder. This lasted, at Syracuse, about a quarter of an hour, when there appeared in the air over the city two bows, the colors extremely bright, after the usual manner, and a third with the extremities inverted, and, as not a single cloud was visible in any part of the sky, the abnormal state of the atmosphere is clear. It was also during this summer that the unusually severe thunder-storm occurred at Geneva that so materially affected the future career of the celebrated Robert Boyle. The earthquakes at Jamaica began on the 17th of June, and their greatest violence seems to have been spent in the mountains. Terrific noises were heard among them at Port Royal during the last shock, and they were so torn and rent as to present a very shattered appearance and quite new forms. In this month Etna emitted extraordinarily loud noises for three days together. A singular circumstance, during this catastrophe at Jamaica, was the derangement of the wind. The land-breeze often failed, and the sea-breeze blew all night, whereas the land-breeze should blow all night and the sea-breeze all day. There was an earthquake on September 8, 1692, in Europe, but I have not yet been able to find out the locality.

Space will not admit of more than noticing some special phenomena of the Sicilian earthquakes, 1693. On the 10th of January the castle of Augusta was blown up by the lightning firing the powder-magazine. At Minco, on the 11th, the shock was attended by "a mighty storm of lightning, thunder, and hail, that lasted six hours." The archbishop's palace at Monreal was set on fire by the lightning. Etna emitted great noises, flames, and ashes, during the shocks that overthrew Catania, but there does not appear to have been eruption. Furla, situated among limestone-quarries, disappeared, and at several parts of the hill the rocks, which were previously almost as white as Geneva marble, had changed, and in the clefts made by the earthquake had become of a burnt color, as if fire and powder had been employed to rend them asunder. Millitello seems to have been destroyed before the 11th of January, for the country-people, who dwelt on the neighboring ridge of mountains, affirmed that it was not to be seen on the morning of that day, to which time, from twelve o'clock on the 8th, it had been concealed in a thick fog. During the interval the mountain that lay on the north side of the town had been split asunder—one portion overwhelming Millitello, so that not an inhabitant escaped. Francofonte, built chiefly of wood, escaped with little damage from the shocks, but was fired by lightning; the spire of the church —wood covered with lead—burnt down, and the nunnery of the Carmelites entirely destroyed so suddenly, that five of the nuns were stifled in their beds. The largest part of the inhabitants of Lnochela escaped by flying from the town on the sudden disappearance of the castle, situated on a rising ground. Ragusa experienced shocks on the 8th, with violent thunder and lightning. At Specufurno, on the 10th,

"from morning till night, there was never heard so violent a storm of thunder and lightning, as if heaven and earth had been mixing together;" the town-house and several other houses were destroyed by it. The peasants on the neighboring hills observed that this lightning had burnt the vines so that no crop could be expected for the season.

The earthquake of London, 1749, also exhibited strong symptoms of electric action. The year abounded with thunder and lightning, coruscations frequently appeared in the air, and the aurora removed to the south, showing upon two occasions unusual colors. Dr. Stephen Hales heard a rushing in his house which ended in an explosion in the air as from a small cannon, and attributed it to the escape of the fluid by the steeple of the church of St. Martin's-in-the-Fields, adjoining. The Rev. J. H. Murray refers to the electrical disturbances on the east coast of South America, contemporaneous with the great earthquakes on the west coast in 1868, and considers them related. He describes one storm, just at the time of the earthquake, as giving "an idea of what the bombardment of Sevastopol must have been like."

The phenomena of seaquake are of a similar character. We have ourselves seen electric clouds thrown into auroral forms contemporaneously with the disturbance of the sea at another locality.

Examples might be extensively multiplied, but the above would seem sufficient to show that a leading cause of earthquake is electric action, and that volcanoes sometimes produce the same by direct convulsion, and at others by disturbing the electric equilibrium of a locality.—*English Mechanic.*

ANIMAL LIFE IN MADAGASCAR.

THE large island of Madagascar has of late excited a special interest among the lovers of natural history; the richness of its soil has been acknowledged, and the character of its vegetation and of its animals classified. During the present century, Europeans have chiefly visited the northern part of the island, and expressed in glowing language their admiration of its shores. The bay of Diego-Suarez, which is situated in the most northerly point of the island, is spoken of as one of the wonders of the world, and that of Passandava most enchanting. This, however, is not a fair picture of the whole; like other islands, it presents very striking contrasts. A recent traveler, M. E. Blanchard, who has visited certain parts of the island, chiefly to explore its mineral resources, describes in his book ("L'Île de Madagascar," J. Claye, *imprimeur*) the great chain of mountains and the

desolate solitudes to the west of Imerina, where there are immense tracts that no one has trodden. In one part, Nature displays her boundless riches, where the native can live without working, and civilized man procure the enjoyments of material life; in another, the ungrateful land scarcely yields any food; the rocks are sterile, the soil is bare, and a stream of water to render the existence of man or beast possible, is not to be found.

Climbing with difficulty the high, abrupt downs, the pathway has to be opened through thorny bushes, and plains stretch out at the summit; not a tree or shrub is to be seen; desolate, uninhabitable, and depressing, as the deserts of Egypt and Arabia. After a long march through the sand, a new scene opens; the nopal is now found growing—a sure index to the abode of man. These plants, upon which the cochineal insect chiefly lives, are natives of America, but have long been naturalized in Africa and the south of Europe; the Arabs no doubt introduced them into Madagascar. Wherever a country is unwatered by streams, they are an invaluable resource for the inhabitants. Here, every family possesses its plantations of nopals, and gathers the fruit in a peculiar manner. With the point of their lances, they adroitly detach them, thus avoiding their redoubtable thorns; and roll them in the sand to get rid of the silky covering which incloses these spikes, afterward peeling them with the iron point of the dart. They appease hunger, assuage thirst, and permit the poor people to live in places where, for weeks together, water is not seen.

In these solitudes, where the forests are immense, animal life can multiply without fear of man, and yet the fauna of Madagascar offer some singular features. The traveler can pass along without fear of the lions, leopards, and panthers of Asia and Africa; neither do zebras and quaggas gallop over the plains. In other countries, wherever the climate is hot enough, monkeys enliven the woods; here, not a single species is to be found. The horse and the ass are unknown; and, what is still more extraordinary, ruminants, such as stags and antelopes, are absent. It is true that there are large herds of cattle, which constitute the great riches of the Malagaches, as the natives of Madagascar are called, but they have been imported probably from the southern part of Asia. This species is remarkable from its boss or lump of fat on the back, and is strikingly beautiful when seen in large herds wandering over the plains. The sheep, too, are peculiar, from their enormous tails, which consist of a mass of fat—a common feature in those belonging to the African Continent. Goats are common, as well as wild-pigs, which ravage the plantations; but these are supposed to have all escaped from vessels, and not to be indigenous to the island.

The monkeys of other lands are, however, replaced by the lemurs—graceful little creatures of many different varieties. There is a great resemblance in their attitude and manner of life to the ape, so that

they have been styled monkeys with the fox's muzzle. Their agility is marvelous; they leap through the air to a great distance, settling on a branch, which perhaps bends under their weight, and dart off again in evolutions of astonishing rapidity. A wood frequented by troops commands the astonishment and admiration of the traveler, from the intelligent appearance and incessant gambols of these lively animals. The largest kinds are about three feet in length, while the smallest are not larger than a rat. The true lemur, which is distinguished by a long snout and tail, prefers fruit for food, but does not object to crunch a small bird, a lizard, or insects. These are diurnal in their habits; while the chirogales, possessing short paws and pointed teeth, shun the light, and only appear in twilight and moonlight, when they make great havoc among lizards and small game. These curious mammifers are characteristic of Madagascar; other species do exist elsewhere, but the nocturnal kind are found nowhere but in this and the Comoro Islands.

In the most solitary parts of the southwest region lives that strange creature, the aye-aye, or chiromys. A nocturnal animal, gentle and timid, it is about the size of a cat, with a large head, round full eyes not dissimilar to those of the owl, an enormous tail, and most extraordinary formation of the fore-paws; the middle finger being long and slender. This, which looks like a deformity, is, in truth, a wonderful arrangement of Nature for its special way of life. As it lives on the larvæ hidden in the trunks of trees, the finger can be easily introduced into the fissures from which it tears the coveted prey. Naturalists think it forms a link between the squirrel and the monkey. The Malagaches seem to be impressed with a superstitious dread of the animal, owing to its sleeping all the day in the most secret haunts; nor do they ever molest it, astonished as they seem to be by its peculiar physiognomy and movements.

There is another class of mammifers peculiar to this island, which are called tendraks by the natives, and seem closely allied to our hedgehogs. Like these, they are covered with spines, but the teeth differ, and the tail is wanting; neither do they roll themselves into a ball, but hide the head between their paws when frightened. Seven or eight species have been discovered, with some variety in the spines, some being soft, and not covering the whole of the body. They are all nocturnal in their habits, and very good when cooked. As for the carnivora, they all belong to a very small type. The wild-cat is a pretty creature. Its back is fawn-colored, traversed by four stripes of reddish-brown, and yellowish-white under the body and the paws. The ichneumon, with its long thin body and shaded skin, also gains the admiration of the traveler; it is a fearful enemy to all small or weak animals, but one of the species feeds greedily on honey. Not the least curious is the cryptoproctus, of the size and appearance of a cat, but with feet formed like those of a bear, the entire sole

resting on the ground. No other example of a plantigrade animal is known.

The masked wild-boar, which is still more ugly than its European fellow, is the only mammifer met with both in Madagascar and Africa. It is a hideous creature, with high withers, low back, and little hair. It boasts of an enormous tubercle, supported by a bony prominence in the jaw, which renders the face of the animal extremely disagreeable. A species of gray squirrel, which lives in hollow trees, and bats, complete the list of the mammifers yet known in Madagascar.

It is very different as regards birds; they can cross immense spaces; and so the tern, the petrel, the albatross, and many other well-known birds, abound in this island. It is a charming sight, on a sunny day, to see flights of ducks with brilliant and varied plumage paddling and diving on the rivers or lakes. One large species, with bronze and violet reflections, like metals, its white head and neck spotted with black, is a great favorite with the natives. A beautiful teal-duck, only known here, has an exquisite blending of brown, fawn, and slate-colored plumage, with fair white wings. In the marshes stalks the proud sultana-hen, with its magnificent blue body, a red patch on its head, and coral feet adorned with a tuft of white feathers, by which it is easily distinguished among the reeds. The jacana, a bird of the water-hen family, is also peculiar to this place; mounted on long legs like stilts, and extremely long feet, it runs through the long grass, or upon the floating water-leaves, with wonderful rapidity.

The sacred ibis of the Egyptians is found in large flocks, as well as the green variety of Europe. The crested ibis is peculiar to the country; a beautiful bird, bright-red, with yellow beak and claws; a green head, from which the long plume of white and green feathers lies back. Another bird, classed among the *Gallinaceæ*, is remarkable for the length of its beak; while the pretty blue and green pigeons afford plenty of sport for the lover of the gun. Near the streams, the nelicourvi, a green-plumaged bird, builds its nest among the leaves, composed of bits of straw and reeds artistically woven together. The magnificent cardinal, in its bright scarlet robe of feathers, black-spotted on the back, haunts the open glades of the forest; and on the banks of streams are numbers of linnets, wagtails, and humming-birds, which are almost as small and graceful as the American ones, in addition to possessing all their beauties. The one which is the most common is also the most beautiful, with its bright-green body shaded with violet; the large feathers of the wings, brown-edged, with a violet band on the breast, succeeded by one of brown; and yellow beneath. The family of cuckoos is well represented; the blue variety is a magnificent bird, common in the woods on the shore.

As for the reptile class, it is pleasant for the traveler to walk through the forests knowing that the venomous species are unknown.

Two hundred years ago, the old traveler Flacourt declared that the serpents were all inoffensive; recent experience confirms the fact. The largest is named *Pelophilus Madagascariensis*. There are others, such as the *Langaha nasuta* and *Crista-galli* (zoölogists having retained the name they bear among the natives), which are very singular, from the prolonged form of the snout, arising from the skin being lengthened out. Beautiful lizards, covered with brilliant scales of olive or fawn, spotted with black, white, and yellow, hide themselves under the stones, in the moss, or in old trees. But Madagascar is especially the land of chameleons; in the heart of the forests, they may be seen crouched on the branches, calm and immovable, rolling their large eyes. The crocodile is the only creature to be feared, and accidents from it are very rare, as the inhabitants greatly object to venturing into water.

The insects of Madagascar offer a thousand types for admiration. There are valuable kinds, furnishing wax, honey, and silk; the first two forming one of the natural riches of the island. The bee peculiar to the country has a black body, red underneath; it is very abundant in the woods, and makes its nest in decayed trunks of trees, whence the Malagaches tear the comb.

But there was an epoch when much more remarkable animals lived in Madagascar. In the marshes near the river Manoumbe, at no great depth, a great number of bones of the hippopotamus, of colossal tortoises, and of the limbs and eggs of the *Œpyornis maximus*, have been found. The eggs of this king of birds are six times larger than those of the ostrich; and it was at first hoped that, in the hitherto unknown solitudes of the interior, some living specimens might be found; that hope has, however, vanished, though it is evident they once existed in great numbers in the southwest part of the island. They were of various species, and of different sizes. At the same period, the hippopotamus must have been abundant, as the bones of fifty skeletons were picked up in a few hours. This species, of very inferior dimensions to that frequenting the Nile, is entirely extinct.—*Chambers's Journal.*

SKETCH OF PROFESSOR STOKES.

THE subject of this notice, GEORGE GABRIEL STOKES, was born August 13, 1819, at Skreen, in the county of Sligo, Ireland, his father being rector of the parish. At an early age he was sent to a school at Dublin, conducted by the Rev. R. H. Wall, D. D. Here he remained for about three years, when he entered a college at Bristol, as a preparation for the university. After two years spent at Bristol, young Stokes, in 1837, entered Pembroke College, University of

Cambridge, and four years later graduated Bachelor of Arts, at the same time winning the highest honors of the university—the Senior Wranglership and the First Smith's Prize. In the same year he was elected to a fellowship in his college. In 1849 he was appointed to the Lucasian chair of Mathematics in the university, and thus became the successor of Newton. Mr. Stokes enjoyed the emoluments of his fellowship until 1857, when he vacated that position by taking a wife. Later, by an amendment of the statutes of Pembroke, he was reinstated in his fellowship. In 1851 he was chosen Fellow of the Royal Society, and in the following year received the Rumford medal "in recognition of his services to the cause of science by the discovery of the change of the refrangibility of light." The "Philosophical Transactions" for 1852 gives an account of this discovery. In 1854 Mr. Stokes was elected one of the secretaries of the Royal Society. He was President of the British Association for the Advancement of Science at the Exeter meeting, 1869. In 1871 the University of Edinburgh conferred upon Prof. Stokes the degree of Doctor of Laws.

It requires merit of no common order to enable a man to attain the high honor of occupying the chair of Newton, at the early age of thirty. Mr. Stokes's election to the Lucasian professorship was a surprise to the undergraduates of Cambridge, who had expected to see the place filled by some man of European fame. But the wisdom of the choice was soon made manifest, and the students of Cambridge recognized in the new professor not only an exceptionally able and learned man, but also one whose whole heart and soul were devoted to the advancement of his pupils. How Prof. Stokes won the confidence and love of the students is told by Prof. P. G. Tait, who at the time was himself an undergraduate at Cambridge. In a memoir recently published in *Nature*, Prof. Tait writes that, a few months after his election to the chair of Mathematics, Prof. Stokes gave public notice that he considered it part of the duties of his office to assist any member of the university in difficulties that he might encounter in his mathematical studies. Here was, thought the students, "a single knight fighting against the whole *mêlée* of the tournament." But they soon discovered their mistake, and felt that the undertaking was the effect of an earnest sense of duty on the conscience of a singularly modest but profoundly learned man.

As a mathematician and physicist, Stokes stands in the foremost rank, whether of his contemporaries or of his predecessors. "Newton's wonderful combination of mathematical power with experimental skill," writes Prof. Tait, "without which the natural philosopher is but a fragment of what he should be, lives again in his successor. Stokes has attacked many questions of the gravest order of difficulty in pure mathematics, and has carried out delicate and complex experimental researches of the highest originality, alike with splendid success. But several of his greatest triumphs have been won in fields

where progress demands that these distinct and rarely associated powers be brought simultaneously into action. For there the mathematician has not merely to save the experimenter from the fruitless labor of pushing his inquiries in directions where he can be sure that (by the processes employed) nothing new is to be learned; he has also to guide him to the exact place at which new knowledge is felt to be both necessary and attainable. It is on this account that few men have ever had so small a percentage of *barren* work, whether mathematical or experimental, as Stokes."

A partial list of Stokes's contributions to science is given in Prof. Tait's memoir. It is there stated that up to 1864 Stokes had published the results of some seventy distinct investigations. Since that year he has published but little, though it is well known that he has *in retentis* several optical and other papers of the very highest order, which he cannot bring himself to publish in an incomplete form. Many of the papers which have been published by Prof. Stokes are of so rigidly mathematical a character that their titles would fail to convey any idea to the non-mathematical mind. To this category belong the papers entitled "Critical Values of the Sums of Periodic Changes" and "Numerical Calculation of Definite Integrals and Infinite Series." The following incomplete list will serve to show the comprehensiveness of Prof. Stokes's researches in applied mathematics:

"On the Friction of Fluids in Motion, and the Equilibrium and Motion of Elastic Solids," 1845; "Effects of the Internal Friction of Fluids on the Motion of Pendulums," 1850.

Of Stokes's papers stating the results of his researches on the "Undulatory Theory of Light," three are cited by Prof. Tait, viz.: "Dynamical Theory of Diffraction," 1849; "On the Colors of Thick Plates," 1851; "On the Formation of the Central Spot of Newton's Rings beyond the Critical Angle," 1848.

The "Report on Double Refraction," in the "British Association Reports for 1862," was drawn up by Prof. Stokes.

"On the Variation of Gravity at the Surface of the Earth," 1849.

"On the Change of the Refrangibility of Light," 1852. This paper contains his famous experimental explanation of fluorescence, which earned for its author his fellowship in the Royal Society.

Among the papers published by Stokes since the year 1864, two are specially worthy of mention, viz.: "On the Long Spectrum of Electric Light," and "On the Absorption Spectrum of Blood."

In conjunction with the late Mr. Vernon Harcourt, Stokes made a highly-valuable experimental inquiry into what is called *Irrationality of Dispersion*, chiefly with a view to the improvement of achromatic telescopes.

"There can be no doubt," writes Prof. Tait, "as was well shown by Sir W. Thomson in his presidential Address to the British Associ-

ation at Edinburgh in 1871, that Stokes (at least as early as 1852) had fully apprehended the physical basis of spectrum analysis, and had pointed out *how* it should be applied to the detection of the constituents of the atmospheres of the suns and stars. Balfour Stewart's experiments and reasoning date from 1858 only, and those of Kirchhoff from 1859."

Prof. Stokes, however, gives due credit to Kirchhoff. Thus, in his Presidential Address to the British Association, in speaking of the applications of the spectroscope, he says:

"But how shall we find in such distant objects as the stars an analogue of the bell which we have assumed in the illustration drawn from sound? What evidence can we ever obtain, even if an examination of their light should present us with rays of definite refrangibility, of the existence in those remote bodies of ponderable matter vibrating in known periods not identical with those corresponding to the refrangibilities of the definite rays which we observe? The answer to this question will involve a reference, which I will endeavor to make as brief as I can, to the splendid researches of Prof. Kirchhoff. The exact coincidence of certain dark lines in the solar spectrum, with bright lines in certain artificial sources of light, had previously been, in one or two instances, observed; but it is to Kirchhoff we owe the inference, from an extension of Prevost's theory of exchanges, that a glowing medium which emits bright light of any particular refrangibility *necessarily* (at that temperature at least) acts as an absorbing medium, extinguishing light of the same refrangibility. In saying this, it is but just to mention that, in relation to radiant heat (whence the transition to light is easy), Kirchhoff was preceded, though unconsciously, by our own countryman, Mr. Balfour Stewart. The inference which Kirchhoff drew from Prevost's theory thus extended, led him to make a careful comparison of the places of the dark lines of the solar spectrum with those of bright lines produced by the incandescent gas or vapor of known elements; and the coincidences were in many cases so remarkable as to establish almost to a certainty the existence of several of the known elements in the solar atmosphere, producing by their absorbing action the dark lines coinciding with the bright lines observed. Among other elements may be mentioned, in particular, hydrogen, the spectrum of which, when traversed by an electric discharge, shows a bright line or band exactly coinciding with the dark line C, and another with the line F.

"Now, Mr. Huggins found that several of the stars show in their spectra dark lines coinciding in position with C and F; and what strengthens the belief that this coincidence, or apparent coincidence, is not merely fortuitous, but is due to a common cause, is, that the two lines are found associated together, both present or both absent. And Kirchhoff's theory suggests that the common cause is the existence of hydrogen in the atmospheres of the sun and certain stars, and its exercise of an absorbing action on the light emitted from beneath."

CORRESPONDENCE.

THE FORM OF LIGHTNING-RODS.

To the Editor of the Popular Science Monthly:

IN a paper in THE POPULAR SCIENCE MONTHLY for August, entitled "The Form of Lightning-Rods," Prof. Phin describes an experiment intended to demonstrate the proposition that electricity of high tension travels through the substance of a conductor independently of its superficies.

Without questioning the general truth of this proposition, I would call attention to one or two flaws in the author's demonstration.

He cites the fact that a moderate charge shatters a strip of gold-leaf, while a stronger one fails to affect a wire having less surface and a greater section. From this he deduces his theorem.

This experiment seems to me unsatisfactory, for the reason that a disruptive force may be supposed to be exerted in both cases, but that the superior strength of the wire enables it to resist what destroys the frail gold-leaf. Of course, the same argument will hold if the effect be ascribed mainly to heat, since but little, comparatively, would suffice to fuse the gold-leaf or even to dissipate it as gas.

Prof. Phin, referring to this experiment, says: "Here we see that, while the electricity was at rest (*static*), the gold-leaf was quite capable of receiving as heavy a charge as the most powerful machine could impart."

It doubtless was "capable of receiving the most powerful charge," but the fact is not proved by the experiment, for, in the position in which the gold-leaf was placed, viz., on the knob of the jar, it was not charged at all!

The charge must have been collected upon the inner coating, through the attraction exercised by the electricity induced upon the exterior. The gold-leaf, in connection with the inside of the jar, was then, properly speaking, no more charged than were objects connected with the outside, e. g., the table, and, to a certain extent, every other object on the surface of the planet.

L. H. ANDREWS.

SPRINGFIELD, MASS., *August* 17, 1875.

To the above Prof. Phin replies as follows:

"1. The first objection is to the experiment in which a gold wire is shown to be capable of carrying off a discharge which destroys a strip of gold-leaf presenting a far greater surface. Whether we attribute the destroying power to heat or to mechanical force, it is a fact that the thin gold-leaf is destroyed while the stouter wire remains uninjured, and this is all that is necessary to be known so far as lightning-rods are concerned.

"2. The second objection is, that the gold-leaf in contact with the knob of the jar is not 'charged.' Of course, if the gold-leaf is not charged, the same remark applies to the knob itself; how, then, does it happen that, under such circumstances, the knob will powerfully attract or repel (according to circumstances) a pith-ball brought near it? Probably the most intense charge of static electricity could be imparted directly from the prime conductor. This we have often done, without injuring the most delicate strip of gold-leaf, though the passage of a spark, even without the aid of a Leyden jar, will destroy a strip three-eighths of an inch wide."

EDITOR'S TABLE.

EXPENSIVENESS OF SCIENTIFIC EDUCATION.

AS we have often said, and as will probably have to be many times repeated and explained before its full meaning is generally appreciated, there are two kinds of education, scientific and non-scientific; or one which brings the mind to bear upon actual things, and another which occupies it with their symbols. One turns the intellect directly upon Nature, and aims to train

it in the acquisition of first-hand knowledge; the other turns it upon books, and exercises the mind upon verbal representations which are accepted in the place of actual things.

This statement, however, though broadly true, requires qualification. Scientific education, of course, neither ignores books nor discredits them for their proper uses; it only subordinates them to its main object—employing them as auxiliaries in the study of Nature. The case is sometimes put extravagantly; extreme statement being thought needful to counteract extreme errors. Prof. Agassiz, for example, as is well known, was often hot in his denunciations of books; but it was their abuse at which his wrath was kindled. He had little patience with the servile habit of learning lessons and quoting books; and he waxed indignant when he saw students stopping with the manual and interposing it between the mind and Nature. His excellent rule was, first learn to know something directly about the subject yourself, and then you will be competent to deal with the representations of others. He saw that it was of primary and vital moment that the student should first of all come at the living phenomena, and learn to read them and think about them independently; and he saw, too, that books are the potent agents by which this desirable object is constantly defeated. Scientific education, therefore, only wars with the perversion of books. Scholastic education, on the other hand, does not propose to go beyond the books. Letters, literature, things written, and the modes of representation, are its ends and its ultimate objects. That the manner is of more account than the matter is the law of gravitation in "culture" or literary education; it governs every thing. The scholar is of course a man, and recognizes as an accident of his being that he is placed in the midst of a system of things which we call Nature. He cannot quite ignore it if he would; he cannot help knowing something of the world he lives in. But he is not concerned about it. He is satisfied with the knowledge of Nature that he picks up inevitably. Natural things, the facts, laws, and order of the world, are not to him objects of mental exercise. He does not recognize them as the means of education; he gives his life to books.

There is, of course, no antagonism between literature and science as mere pursuits; but in the field of education, or as representing methods of cultivating the human mind, they are inveterate rivals. This was less apparent when education was limited to the favored classes, and the scientists and the *littérateurs* could go their respective ways in peace. But in the new dispensation of popular enlightenment, when everybody is to be educated and everybody is to be taxed for the purpose, a conflict arises as to which of the two systems shall have precedence. The people are to be secured a larger measure of mental cultivation. It is their destiny to be occupied with the matter and forces of Nature, and they are creatures of an inexorable system of natural law: shall their education be conformed to these facts, and deal with the direct phenomena of experience, or shall it stop with symbols and be predominantly an affair of books? The issue can neither be forced nor escaped; it belongs to time and the growth of ideas. It is not that Literature is in the saddle and is to be unhorsed by Science; but the undoubted tendencies of the past must work in future with increasing power, and lead, we believe, to the ultimate ascendency of the study of natural science.

But, while recognizing the direction of the great mental movement which marks especially the present age, it will be wise to moderate our expectations and recognize also the formidable character of the difficulties which stand in the way of scientific education. Among these is its great expensiveness. Literary education has here an enormous advantage. Books are cheap. It

is not the label that costs, but the thing labeled. Economy admonishes us to stop with symbols. Phenomena are displayed only as realities; and things real are property and must be paid for. Experimental facilities are expensive, and museum collections represent immense labor. This is a potent reason why there is so much sham in so-called scientific education; or, perhaps, we might more properly say why it falls so far short of what is expected from it. The poor student who cannot get the objects and materials for observation and experiment, is tempted if not compelled to make such shift as he can with books and pictures. This is a difference between the two systems of education which is deep and must continue, and it will operate powerfully to hinder the popular spread of true science. There are, of course, differences in the expensiveness of different branches of scientific study; botany, for example, being cheaper than chemistry. Of the two classes that may be taken generally as most ignorant of the science of their business, cooks and congressmen, it will cost at least ten times more properly to educate the former than the latter.

Yet this difficulty of scientific education is by no means incapable of mitigation, although but comparatively little has thus far been done to overcome it. The training of professional scientific students for the work of research has hitherto engrossed the main attention, and here much has been done to simplify and cheapen operations. Experimental physics is more expensive than chemistry, but efficient efforts are making to reduce the old scales of cost. We notice that, in the scientific school at South Kensington in London, they have adopted the plan of putting the student methodically at work, at the outset, to make his own apparatus. This is an important step, as a short apprenticeship of this kind soon renders him to a very considerable degree independent of instrument-makers, and enables him to go on with his inquiries by utilizing resources that may come to hand in almost any circumstances.

Yet the problem from our point of view is still unresolved. Scientific education, in its popular aspect, does not aim to make investigators or discoverers; it only proposes to acquaint general students with some of the branches of science which may be selected, but to do it by actual familiarity with their subject-matter. What may be now fairly demanded is, that a certain portion of physics, chemistry, botany, or zoölogy, be actually mastered; that is, their phenomena and facts shall be seen, and their principles known by all who take a liberal course of study. This is indispensable to counteract the evils of a purely book education, and to avoid the uncertainty and illusiveness that prevail in the realm of mere words. The importance of this end being admitted, the question remains, how to provide the most economical facilities for this kind of study. It is beyond doubt possible, by the employment of suitable objects that are everywhere available, to give reality and thoroughness to scientific study without great expense; but the method of doing this has yet to be elaborated. Perhaps the only exception to this statement is botany, which can be studied so cheaply that there is no excuse, on the score of cost, for not introducing it forthwith into all common schools. A method has been developed, which is rigidly based upon the principle that the pupil shall study the actual objects at first hand, so that he may "know what he knows" of this interesting subject, and not stop with book representations of it, while the objects of examination are to be had everywhere by merely plucking them. Something like this, as far as it shall prove possible, is yet to be accomplished for the popular study of physics, chemistry, and zoölogy.

PROGRESS OF NATURAL HISTORY.

A COMPREHENSIVE German work on natural history, entitled a "Hand-Book of Zoölogy," by Prof. Carus, assisted by Prof. Gerstäcker, has just been completed. Its publication by Engelmann, of Leipsic, was begun in 1863, and the last volume has been recently issued. The work is reviewed in *Nature* by Prof. E. Ray Lancaster (editor of Haeckel's great work, soon to be issued), and of the general merits of the Hand-book he speaks as follows:

"As the latest complete systematic treatise on the animal kingdom, and one executed with the exercise of most conscientious care, and a very exceptional knowledge of the vast variety of zoölogical publications which now almost daily issue from the press, this work is one which is sure to render eminent service to all zoölogists. We can speak to the usefulness of the earlier volume, from an experience of some years, and there is every reason to believe that the one just completed will be found as efficient."

Having pointed out, with some detail, the scope and characteristics of Prof. Carus's treatise, Dr. Lancaster proceeds to estimate it with more special reference to the later advances of biological theory, and his remarks upon this subject are so opportune and instructive, that we quote them at length. They afford an excellent illustration of the broad applicability and practical bearing of these modern doctrines in relation to life, doctrines which are still characterized by many as "unfruitful speculations."

"Prof. Carus suffers in this book as in his 'History of Zoölogy,' from the unphilosophic conception of the scope and tendencies of that division of biology which its early history has forced upon modern science. In England our newest and most conservative university continues to draw a broad distinction between what is called comparative anatomy and what is called zoölogy. By some accident zoölogy is the term which has become connected with the special work of arranging specimens and naming species which is carried on in great museums, and which has gone on in museums since the days when 'objects of natural history,' and other curiosities, first attracted serious attention in the sixteenth century. Accordingly, zoölogy, in this limited sense, has taken the direction indicated by the requirements of the curators of museums, and is supposed to consist in the study of animals not as they are *in toto*, but as they are for the purposes of the species-maker and collector. In this limited zoölogy, external characters, or the characters of easily-preserved parts which on account of their conspicuousness or durability are valuable for the ready discrimination of the various specific forms, have acquired a first place in consideration to which their real significance as evidence of affinity or separation does not entitle them.

"From time to time the limited zoölogists have adopted or accepted from the comparative anatomists hints or conclusions, and have worked them into their schemes of classification. But it does seem to be time in these days, when pretty nearly all persons are agreed that the most natural classification of the animal kingdom is that which is the nearest expression of the animal pedigree, that systematic works on zoölogy should be emancipated from the hereditary tendencies of the old treatises, and should present to us the classes and orders of the animal kingdom defined not by the enumeration of easily-recognized 'marks,' but by reference to the deeper and more thorough-going characteristics which indicate blood relationships. We have to note in the 'Handbuch' the not unfrequent citation of superficial and insignificant characteristics in the brief diagnoses of taxonomic groups, which seems in so excellent a work to be due to a purposeless survival of the features of a moribund zoölogy that would know nothing of 'insides,' and still less of the doctrine of filiation. For instance, the very first thing which we are told of the vertebrata, in the short diagnosis of the group, is, that they are 'animals with laterally symmetrical, elongated, externally unsegmented bodies;' of the fishes, that they have the 'skin covered with scales or plates, seldom naked;' of the mollusca, that they have a 'laterally symmetrical, compressed body devoid of segmentation, often inclosed in a single (generally spirally-twisted) or double calcareous shell.'

"It would be unjust to suggest that Prof. Carus, who long ago did so much to establish zoölogical classification on an anatomical basis, is not fully alive to the necessity, at the present day, of taking the wide biological view of animal morphology; but cer-

tainly the form in which parts of the book are cast savors of the past epoch. It may be said that the object of the book is to present the 'facts' of zoölogy in a logical order; and that this sufficiently explains the arrangements to which objection might be taken as above, viz., the commencing with the higher instead of the lower groups, the prominent position assigned to external and little-significant characters, the absence of any recognition of the leading doctrine of modern zoölogy, the doctrine of filiation. To this there is nothing to say excepting that of the very *many* logical methods of treatment possible in a hand-book of zoölogy, many are easy to follow out, and that one, which aims at presenting a logical classification of the kind spoken of by Mill, in which objects 'are arranged in such groups, and those groups in such an order as shall best conduce to the ascertainment and remembrance of their laws,' is a very difficult one to follow out. This kind of classification involves nothing less than an attempt (however inadequate) to trace the animal pedigree; for the laws to be ascertained and remembered are the laws of heredity and adaptation. We may regret, then, that so able a zoölogist as Prof. Carus has remained in the old grooves and not ventured on to the inevitable track where Gegenbaur and Haeckel have preceded him."

LITERARY NOTICES.

PROBLEMS OF LIFE AND MIND. By GEORGE HENRY LEWES. First Series, Vol. II. Boston: J. R. Osgood & Co., pp. 487. Price, $3.

THE "problems" discussed by Mr. Lewes in the two volumes which constitute his first series are six in number. Of these, the first, "Limitations of Knowledge," was considered in the preceding volume; the rest are considered in the volume before us. The author's purpose in this series is "to lay down the foundations of a creed, by exhibiting the method which determines all successful inquiry, and by specifying certain general results reached on that method." Thoroughly imbued with the scientific spirit, Mr. Lewes applies to metaphysical discussions the same methods which have in modern times given such brilliant results in the field of natural science. The problems which he discusses are among the most intricate which have worried the mind of man from the dawn of reason. They have been the object of profound study ever since philosophy first had a place in human thought; men have viewed them from every side, and attempted their solution in every conceivable way, but still they remain in all their pristine obscurity. The scientific method of investigation has at last been brought to bear upon these problems, and already we seem to be gaining some headway, under the guidance of Spencer, Bain, Lewes, and their fellows.

The first problem discussed in the volume before us is that of *Certitude*. The author's one test of truth, or of certitude, is the principle of equivalence. When two terms have the same import, i. e., are *equivalent*, they may be predicated of one another; and all errors, both in reasoning and conduct, arise from assuming equivalence in terms where it does not exist. Mathematical truths are exact, necessary, only when the terms in which they are stated are equivalent; mathematical propositions become inexact, or contingent, whenever they are applied to cases involving conditions not included in the terms. The objection might be made that this reduces truth to an identical proposition—"a thing is itself." Yet, in propounding any truth, what more does one intend than to express *what the facts are;* and what is a statement of facts more than the assertion *that they are what they are?* When the two terms of a proposition can be thus shown to be equivalent, the proposition is a truth, and we possess certitude of it. Mr. Lewes shows that this principle of equivalence is the same as the Universal Postulate of Herbert Spencer, of which it is merely the positive statement. Our author's principle is, "Truth is the equivalence of its terms." He states Spencer's principle as follows: "Whenever a subject and predicate are so united that the one term is incapable of appearing to thought without the other, the proposition is necessary; and its negative being unthinkable, the proposition itself must be true." Our author further shows that the three scholastic principles, Identity, Contradiction, and Ratio Sufficiens, are all reducible to the principle of equivalence.

In discussing his second [third] problem, "From the Known to the Unknown," the author analyzes the process of the growth of knowledge; the operation called by logicians Judgment; the process of Ratiocination; Induction, Deduction, and Reduction. He points out the capital error of the subjective or speculative method of advancing from the known to the unknown, as distinguished from the objective or scientific method. The metaphysical thinker imposes his conceptions on phenomena, instead of observing them; he trusts the validity of inferences he has not tested. The scientific thinker, on the contrary, is, or ought to be, on his guard against unverified deduction, and treats it as a tentative process. The process called by the author *Reduction* serves in the hands of the scientific investigator as a check, a test, of his inductions and deductions. Deduction and induction extend knowledge by generalizing acquired results, but reduction criticises these results—retraces their formation step by step, and thus gives to inference a firm basis on sensation. Thus checked and tested at every step, induction and deduction become very serviceable instruments for the discovery of truth. Without such checks and tests their results are simply illusory.

But space fails us to follow the author in his discussion of the remaining three problems, "Matter and Force," "Force and Cause," and "The Absolute in the Correlations of Feeling and Motion." This work of Mr. Lewes is undoubtedly entitled to rank among the highest intellectual efforts of the age.

PRINTING FOR THE BLIND. Report of a Committee of the Social Science Association, at the General Session in Detroit, Michigan, May, 1875. Boston: Alfred Mudge & Son, Printers.

THIS report would have been more satisfactory had it been prepared by some person familiar with the education of the blind. Some of its statements are so remarkable that we are unwilling to accept them until they have been indorsed by those actually engaged in the work of teaching the blind. In it we are informed that the blind acquire knowledge through reading "painfully;" that "they study geography, algebra, and geometry under heavy disadvantages;" that "composition is for them very difficult because of the time and labor required for the mechanical operation of writing;" that "even the best-equipped asylums (*sic*) are but scantily provided with the most indispensable tools for studying geography and arithmetic." All this is contrary to the generally-received opinions in reference to the education of the blind. We have heard that blind children of tender years learn to read quickly and easily with their fingers; and that they enjoy "Robinson Crusoe" and the "Old Curiosity-Shop," for example, as much as any children. We had supposed, too, that in the study of mathematics the blind possessed some advantages. We had supposed that the art of composition was the hardest to teach to deaf-mutes, and that eminent blind writers as well as blind mathematicians were numerous. There is no other appliance for instructing children, whether sighted or blind, in geography, so complete as dissected relief-maps. We doubt whether in all the schools of New York such maps are to be found except in the two schools for the blind. Was it elsewhere than in a school for the blind that Mr. Ruggles conceived the ideas of his inventions for facilitating the education of the blind? For this report recommends the founding of an institution to devise and construct such appliances entirely separate from any school for the blind. And its authors find indorsement for this scheme in a resolution adopted by the Association of Teachers for the Blind, which, as we read it, simply declares that that Association had found it impossible to work with Mr. Ruggles. This report presents but one side of the case. We shall wait to hear the other side, that of the teachers of the blind, before we decide upon the subject.

REPORT OF THE ASTRONOMER ROYAL TO THE BOARD OF VISITORS OF THE ROYAL OBSERVATORY, GREENWICH. Read at the Annual Visitation of the Royal Observatory, June 5, 1875.

IN 1835 the present Astronomer Royal (then Director of the Observatory of the University of Cambridge, England) was called to fill the most important astronomical post in the world, namely, the director-

ship of the Royal Observatory at Greenwich. Since that time he has regularly presented to the Board of Visitors of the Royal Observatory an annual report, and of these the *fortieth* lies before us. In many respects it is like its predecessors; it gives, as they have done, full, even minute accounts of the present condition of the "Buildings and Grounds," of the "Movable Property," of the "Manuscripts," of the "Library," of the "Astronomical Instruments" (in detail), of the "Astronomical Observations" (also in great but necessary detail), of "Spectroscopic and Photographic Observations," of the state of the "Reduction of Astronomical Observations," and of the "Reduction of Photographic and Spectroscopic Observations," of the "Printing" of all the results, of "Magnetic and Meteorological Observations," of the "Chronometers, Time Signals, and Regulation of External Clocks," of the "Personal Establishment," of "Extraneous Work;" and it closes, as its predecessors have done, with a few concise "Remarks" which this year are more interesting and important even than in preceding years.

In other Reports it has been the custom of the Astronomer Royal to draw whatever lessons seemed proper from the work of the past years for the guidance of the observatory in the future, and this has been done in the most concise manner. In this Report the doings of the Observatory in the past and its work for the years to come are spoken of with more freedom and fullness; with so much freedom as to lead some of Mr. Airy's critics in England to speak of it with a kind of fierce joy as his "Valedictory," although nothing is said in it of his retirement. It is impossible to read it without intense interest and without exclaiming, "What a memorable valedictory it would make!"

For forty years the present Astronomer Royal has been the active head of the Greenwich Observatory, and he has been in the most active way concerned in many scientific councils; as he says, "there is not a single assistant or a single instrument in use of those which formed the establishment in 1835," and yet in all these years he has kept steadily one main object in view, and as far as one man can attain it he has attained it. He has gained, with the success of his astronomical plans, the entire and thorough respect and esteem of the scientific world in general, and he may now lay down, if he will, the duties which he has borne so long, sure of the honor and admiration of two generations of his contemporaries.

He points out in this Report, as he has insisted in other Reports, that the Greenwich Observatory was expressly built for promoting methods for determining the longitude at sea, and he shows how the work of Flamsteed, Halley, Bradley, Maskelyne, and Pond (his illustrious predecessors) has been more or less steadily devoted to this object. By none of these, however, has this end been so unremittingly followed as by Airy himself. All the main instruments which the observatory at present possesses, with the exception of the equatorial, may be truly said to have been designed by him with principal reference to the determination of the elements upon which a knowledge of the motion of the moon depends. "Elaborate Star Catalogues" have been formed and immediately published, which are deduced in a uniform manner from the observations, which were made in a uniform way. One steady plan has been followed from 1835 until now, by which results of the very highest value have been attained. The whole astronomical work has been done in one way, and that a wise one; it has been all reduced in one way, probably the best one, and it has been promptly published. This alone would lead to great success. But this is not all: the masses of observations of the moon and major planets which had accumulated from 1750 to 1835 have been carefully taken up, separated, sifted, and discussed upon a predetermined and elaborate plan, and immediately made available to theoretical astronomers. "The lunar reductions are probably the greatest single work ever undertaken in astronomy," so Airy himself says, and he is right beyond a doubt. The needs of astronomy and navigation have been constantly kept in view; the subject of the laws of magnetism in iron ships has been carefully studied, and methods for the correction of ships' compasses have been devised, which are used throughout the world;

regular magnetic observations have been maintained; time-signals are sent all over the kingdom daily, and time-balls are dropped from points such that outgoing ships may see them plainly, and thus regulate their chronometers to Greenwich time on the eve of their departure for sea, and multitudes of chronometers have been tested, purchased, rated, and distributed to seagoing vessels and to scientific expeditions. Meteorological phenomena have been scrupulously registered by approved methods.

Extended experiments on the attraction of mountain-masses were made by Maskelyne, and Airy's Haston-Colliery pendulum experiment is too well known to require more than a mention. Constant assistance has been given to the Government in the training of observers for the transit of Venus, for boundary and other surveys, and for comparison and determination of standards of length, and in many other ways, which the Astronomer Royal does not recount in this Report, but which are well known. His own researches on the theories of the moon and planets, and on scores of allied topics, have made the observatory known throughout the world.

True to the traditions which have brought Greenwich its great success, the Astronomer Royal reiterates in this Report the importance of holding fast to "the fundamental idea"—that of meridional observations; and he indicates that if the force of the observatory must be reduced, that reduction should take place in the photographic and spectroscopic work. He says truly that "the [Royal] Observatory is not the place for new physical investigations," but that it is "well adapted for following out any which . . . have been reduced to laws susceptible of verification by daily observation." He lays down once more and very plainly the principles which have guided him in his long series of useful and honorable labors, and it is well worth the while of all who are interested in astronomy to read this concise expression of them.

We see a new example of how much useful and valuable work may be done in science by the mere force of *persistent* effort in the right direction, and this is a lesson which America needs to take well to heart. By virtue of attention to it, Greenwich can claim that what Delambre said years ago is now doubly true—that if by some great revolution the sciences had perished, while the collection of Greenwich observations alone, with a few methods of calculation, had survived the general wreck, there would still remain sufficient materials for reconstructing the whole edifice of astronomical science.

A Summer in Norway. With Notes on the Industries, Habits, Customs, and Peculiarities of the People, the History and Institutions of the Country, its Climate, Topography, and Productions. Also an Account of the Red Deer, Reindeer, and Elk. By John Dean Caton, LL. D., ex-Chief-Justice of the Supreme Court of the State of Illinois. Chicago: Jansen, McClurg & Co., 1875. Price, $2.50.

We follow with interest the traveler who describes countries and peoples not familiar to us. For this reason we are pleased with Judge Caton's volume, which presents to us a series of pictures, sometimes vividly drawn, of scenery and life on the coast of Norway. His route was from Aalesund, a seaport town in Southern Norway, to Hammerfest, which is more than four degrees within the Arctic Circle, and is the most northerly town in Europe. He also gives an interesting account of a visit to North Cape, made by some traveling companions.

The journey of Judge Caton and his party was by steamers, and nearly all the way among the rocky islands which line the coast. That which seems to have most impressed the party was the perpetual presence of daylight. Day after day the midnight came, but no darkness. This, which was at first pleasing from its novelty, became excessively wearisome before the journey was ended.

The steamer made frequent stops along the coast, but nowhere came alongside the docks to discharge and receive passengers and freight. All this must be done by small boats. The author thought that the most stupid thing he saw in Norway.

Fishing is the principal business of the coast inhabitants—the principal season for cod being in February and March. The rocks were in many places covered with these fish drying for market, or else piled

in stacks after being dried. The journey was made in midsummer, and the melting snows fed innumerable streams which were tumbling over the rocks. The scenery was everywhere beautiful and grand.

At Hammerfest no ice forms in tide-water during winter, and steamers continue their trips from Christiania to Tromsöe near Hammerfest as in summer. Snow, however, falls on the ground quite to the coast, and in great quantity on the mountains. This modification of ocean and coast climate is due to the Gulf Stream.

The author speaks in high terms of the manners, habits, and morals of the Norwegians, but less favorably of the Lapps as respects their culture and refinement. Their morals, however, are good. Those from the mountain districts are rich in their flocks of reindeer. Of these he saw immense droves, but they did not relish the odor of Americans, and he could best approach them against the wind. A chapter is devoted to this animal, and we are promised a volume by Judge Caton on the American and European deer and their domestication.

THE SANITARY JOURNAL. Edited by EDWARD PLAYTER, M. D. Toronto: Dudley & Burns. Monthly. $2.00 per annum.

THIS is a new venture in the periodical field, having commenced its career a few months ago. Both in its editorial and its selected matter it gives evidence of being conducted with ability. It is to be hoped that the enterprise will be so sustained by the Canadian public, that the editor may be enabled to make good his promise of enlarging the *Journal* at the beginning of next year.

ON THE COMPOSITION OF THE GROUND ATMOSPHERE, TOGETHER WITH SOME EXAMINATIONS OF THE AIR IN SMOKING-CARS. By Prof. WM. RIPLEY NICHOLS, of the Massachusetts Institute of Technology.

PROF. NICHOLS presents in this paper the results of interesting investigations of the quantity and properties of air contained in the soil under a great variety of circumstances; and especially in respect to changes produced in it by processes of organic decay in the soil at considerable depths. The paper, which is of much value, is embodied in the "Sixth Annual Report of the Massachusetts State Board of Health."

NAVIGATION IN THEORY AND PRACTICE. By HENRY EVERS, LL. D. 263 pages, 12mo. New York: G. P. Putnam's Sons, 1875. Price $1.50.

THIS book is one of the volumes of an English advanced science series of popular text-books, republished in this country. The work is intended to give the student a clear insight into the theory and practice of navigation. It has been the aim of the writer to make the subject as easy and practical as possible, by presenting the definitions, illustrations, etc., in every variety of aspect. The book comprises thirteen chapters, treating successively and in detail the following subjects: "Definitions and Preliminary Illustrations," "The Compass and its Declination," "The Log, Log-line, and Log-glass," "Plane Sailing," "Traverse Sailing," "Current Sailing," "The Day's Work," "Parallel Sailing," "Middle Latitude Sailing," "Mercator's Sailing," "Great Circle Sailing," "Sailing to Windward or plying to Windward," "Oblique and Current Sailings," and to each chapter are appended numerous examples, illustrations, and exercises.

CONTRIBUTIONS TO THE THEORY OF SOLUBILITY. By ISIDOR WALZ, Ph. D. Philadelphia: Collins, 1875.

THIS paper is a reprint from the *American Chemist* for February, 1875, in which the author attempts to trace some relations between the solubility of substances, their specific volume, and chemical constitution.

Solution he defines to be the penetration of the molecules of one or more substances into the intra-molecular spaces of another substance. Under this definition are given five distinct classes of solubility, thus: of solids in liquids, of liquids in liquids, of gases in liquids, of solids in solids, including alloys, and of gases in solids, as diffusion of gases through metals. The subject is carefully treated, and is presented in a perspicuous and agreeable manner.

HARVARD UNIVERSITY. Bulletin of the Bussey Institution, Jamaica Plain, Boston. Part IV. Cambridge: Press of John Wilson & Son, 1875.

OF the six articles which compose the present number, four are especially important as giving the results of original re-

search. Three of these are by F. H. Storer, Professor of Agricultural Chemistry, and are of direct and practical value. One is a "Record of Trials of Various Fertilizers upon the Plain-field of Bussey Institution," another is a "Report on some Analyses of Salt-Marsh Hay and Bog-Hay," and the third one is on the "Fodder Value of Apples." In this last one Prof. Storer says that, while apples contain a very small percentage of nitrogenous matter, they are not to be overlooked as a food for cattle and swine, and should be used with peas, beans, oil-cake, or other highly-nitrogenized food.

An able article is contributed by Prof. Farlow on "Potato Rot," which is illustrated, and one by Prof. Slade on "The Importance of the Study of Applied Zoölogy to the Practical Agriculturist."

SECOND GEOLOGICAL SURVEY OF PENNSYLVANIA, 1874. Preliminary Report on the Mineralogy of Pennsylvania. By F. A. GENTH. With an Appendix on the Hydrocarbon Compounds, by SAMUEL P. SADTLER. Harrisburg: Published by the Board of Commissioners for the Second Geological Survey, 1875.

THIS report by Prof. Genth, to be followed by a thorough work on the mineralogy of the State, is an excellent handbook of the minerals of Pennsylvania, and of their localities. Most of the minerals of the State are fully and clearly described, and their analyses, many of which are new, are given. The system of classification adopted is that of Prof. Dana, and the report, although submitted as a preliminary one, is indispensable to every student of the mineralogy of Pennsylvania. The report contains a topographical map of the State, and its general thoroughness is shown in its elaborate index.

PUBLICATIONS RECEIVED.

The Better Way: an Appeal to *Men*. By A. E. Newton. New York: Wood & Holbrook. Pp. 48.

Primer of Political Economy. By A. B. Mason and J. J. Lalor. Chicago: Jansen, McClurg & Co. Pp. 67. Price, 75 cents.

Views and Interviews on Journalism. By Charles F. Wingate. New York: F. B. Patterson. Pp. 372.

Geological Survey of Indiana, 1874. By E. T. Cox. Pp. 287. Four Maps.

German Classics. Die Piccolomini; edited by J. M. Hart. New York: Putnams. Pp. 250. Price, $1.25.

Contributions to the Laboratory of the Missouri State University. By P. Schweitzer, Ph. D. Pp. 38.

Notes on Certain Explosive Agents. By W. N. Hill, S. B. Boston: John Allen. Pp. 71. Price, $1.00.

Accidents, Emergencies, and Poisons. Pp. 126. *Also*, Care of the Sick. Pp. 72. Published for free distribution by the Mutual Life Insurance Company of New York.

Preventive Medicine. An Address. By Charles C. F. Gay, M. D. Pp. 12.

The Clinical Thermoscope. By E. Seguin, M. D. Pp. 8. New York: Putnams.

Pseudomorphs of Chlorite after Garnet. By R. Pumpelly. With a Plate. Pp. 4.

Affairs at Red Cloud Agency. By Prof. O. C. Marsh. Pp. 38.

Proceedings at the Eighth Annual Meeting of the Free Religious Association. Boston: Cochrane & Sampson. Pp. 79. Price 35 cents.

Bacteria. By L. A. Stimson, M. D. New York: D. Appleton & Co. Pp. 34.

Examination of Gases from the Meteorite of February 12, 1875. By A. W Wright. Pp. 6.

Report on Trichinosis. By G. Sutton, M. D. Pp. 23.

Catalogue of American, British, German, and French Periodicals. New York: E. Steiger, 22 Frankfort Street. Pp. 16.

On a Fœtal Manatee and Cetacean. By Prof. B. G. Wilder. Pp. 11.

The Age of Ice in Britain. By Prof. Geikie. Pp. 32. *Also*, Insects of the Forest. By A. S. Packard, Jr. Pp. 32. Boston: Estes & Lauriat. Price, 25 cents each.

MISCELLANY.

Detroit Meeting of the American Association for the Advancement of Science.—The American Association for the Advancement of Science met at Detroit, August 11th, and remained in session a week. Less than the

average number of members were present, but in all other respects the meeting was considered to be quite up to the standard of former years. Increased vigilance by the sectional committee, in the examination of papers offered, resulted in a marked improvement in the interest of the proceedings. Probably at no time in the history of the Association were so many papers rejected as at this meeting; not because they were inferior in merit to many presented at former meetings, but because it was felt that from year to year the time of the Association had been too much occupied in hearing papers read which fell short of a reasonable standard of excellence. It will be another move in the right direction, if the Association will peremptorily check useless discussion, which wastes more valuable time than even the reading of inferior papers. When the presidents of the sections shall have the courage to do this, then will the Association do its allotted work more effectually, and its primary object, the "advancement of science," will be more surely attained. It is worthy of note that the chief papers read in the biological section were in favor of the principle of evolution. "Facts for Darwin" were contributed by Profs. Wm. S. Barnard, E. D. Cope, E. S. Morse, Burt G. Wilder, Messrs. A. R. Grote and Henry Gilman, and Hon. L. H. Morgan. Abstracts of these and other valuable papers follow. The suggestion of ex-President Le Conte, that the national Government appoint a scientific commission for the investigation and repression of our more destructive insect pests, is timely and important, and we hope that, in the interest of both agriculture and pure science, the newspapers of the country will unite in urging the matter upon the attention of the authorities. The value of such commissions, when properly constituted, has been abundantly demonstrated in other countries, and, as Prof. Riley pointed out in some remarks following those of Prof. Le Conte, there is no country in the world more in need of the services of such a commission than the United States at the present time.

The officers of the Association elected for the ensuing year are: President, Wm. B. Rogers, Boston; General Secretary, Thos. Mendenhall, Columbus, O.; Vice-President Section A, Chas. A. Young, Hanover, N. H.; Vice-President Section B, Edward S. Morse, Salem, Mass.; Secretary Section A, Arthur W. Wright, New Haven; Secretary Section B, Albert H. Tuttle, Columbus, O.; Permanent Secretary, F. W. Putnam, Salem, Mass.; Treasurer, Thomas T. Boune, Boston.

The twenty-fifth meeting of the Association is appointed in the city of Buffalo, to commence August 23, 1876.

Evidence of Evolution.—The scientific world has for some time been in possession of the fossil wealth of Wyoming and Dakota, but the remains of those early mammalian races had not been placed in relations with the genesis of the human species till Prof. Cope's investigations were published to the Association. The paper which details these researches and their results was no doubt the most important document presented to the Association, and hence we give a rather lengthy abstract of it. According to Prof. Cope, to prove the doctrine of evolution, two propositions must be established: 1. That there exists an orderly succession of structure, corresponding with succession in time; and, 2. That the terms of this succession of structure (species, etc.) actually display transition, or connection by intermediate forms. The first is to be demonstrated from paleontology; the proof of the second is restricted to the observation of living varieties and the discovery of connecting forms.

The structure of the feet is taken to be the best criterion of descent or relationship. The author distinguishes several types of structure of the foot in recent land-mammals, as the *plantigrade*, the *carnivorous*, the *horse*, and the *ox* type. The simplest form of feet is seen in the lowest vertebrata, as lizards, salamanders, which have five toes, with numerous separate bones of the palm and sole which they apply to the ground in walking, The plantigrade type approaches this. In the hind-foot a succession of forms leads from this generalized, many-toed, plantigrade type, to the extreme specializations of the horse and the ox. In any figure of the bones of the human foot, the reader will see two rows called *tarsal* bones, the second row

being followed by a row of long bones, called *metatarsal*, attached to which are the toe-bones. Observe, further, the form and position of the heel-bone and the astragalus, the ankle-joint. Above the foot, and articulating with the astragalus, are two bones, one small (fibula), the other large (tibia). In many reptiles the ends of these bones are nearly equal. Now, in Bathmodon, a mammal from the lowest Eocene Tertiary of New Mexico and Wyoming, the tibia and fibula articulate with the astragalus and heel-bone. As in man, the fibula is the smaller, and the heel-bone is short; the animal walked on the entire sole. From Bathmodon to Horse, on the one side, and Ox on the other, there is a complete succession of intermediate forms, corresponding to succession in time. Thus in Bathmodon the astragalus is nearly flat, while in the ox its upper surface presents a grooved face of a pulley, its under surface an angulated pulley-face, and a small convexity is presented to the hollow of the heel-bone behind. The progression toward this form from Bathmodon embraces these terms: Bathmodon (a gap filled by partially-known genera), Hippopotamus, Peccary, or Oreodon, Deer, Ox. The succession of feet to the one-toed extreme, Bathmodon, Titanotherium (in the Miocene), Tapir, Horse. In the heel-bone there is a succession from the short and flat form of Bathmodon to the long and slender one of the horse and ruminants, and this increase of length is associated with elongation of the bones of the toes, and the passage from the plantigrade to the digitigrade type. Another succession is seen in the diminished number of toes. The series commences in the primitive Eocene types with five digits; in the various series leading to the horse, the ox, the hyena, the cat, the reduction proceeds by the loss of a toe from one side or the other, until, in the ruminants, but two are left, and in the horse but one. In like manner the two bones of the leg, which articulate with the foot and hand, exhibit a succession of changes.

The relation of man to this history is significant. His limbs are those of the primitive type, so common in the Eocene. He is plantigrade, has five toes, separate carpals and tarsals, short heel, flat astragalus, and neither hoofs nor claws, but something intermediate between the two. The bones of the forearm and leg are not so unequal as in the higher types, and the ankle-joint is not so perfect.

A like succession is shown to exist in the forms of the teeth; but we have not the space for even the briefest synopsis of the author's remarks on this point. Thus in limbs and in teeth man retains the characters of the primitive type. From the generalized mammalian fauna of the Eocene the carnivora developed a highly-organized apparatus for the destruction of life. The cloven-footed and odd-toed hoofed orders, are the result of constantly-increasing growth of the appliances for rapid motion over the ground. The ancestors of the carnivora were developing the arts and cruelty of the chase; those of the hoofed orders were developing speed; those of the quadrumana neither speed nor weapons of defense, and nothing was left to them but arboreal life. They took to the trees, and developed the prehensile powers of the feet. In limb and tooth, and digestive system, they remain nearly in the generalized condition from which the other orders have risen. Man's prominence consists solely in the complexity and size of his brain. While the order to which he belongs has made but little progress since the Eocene, in perfecting the organization of the skeleton, it has accomplished the greatest work of all time—the evolution of the human brain and its functions. "The race has not been to the swift, nor the battle to the strong."

Muscular Structure of the Hands and Feet.—While Prof. Cope has been working on the osteology of the hand and foot, Dr. William S. Barnard has been studying their myology, or muscular structure. On the history of the muscles the fossil world can throw no light, but Dr. Barnard's investigations of living types seem to demonstrate that muscles have had a history no less significant than the bones. Prof. Cope has shown that, osteologically, the human foot is of ancient pattern. What is it myologically? Let the reader attentively study his own foot; let him experiment on the toes. Try to flex them, and they move, but rather

clumsily. Try to flex a single toe, keeping the rest straight, and the thing will be found to be impossible; they all move together. The big toe may have a little independence, but not much. The Duke of Argyll has lately said, that we can know the animal by looking down from our higher selves upon our lower selves. If the duke would look at an opossum flexing its toes in climbing, and then look down on his own foot, he would have a closer acquaintance with the marsupial. Our toes have the same communal movements as those of the opossum. But our fingers we can flex one at a time or any way we like.

Now, Dr. Barnard's dissections would seem to show that the muscles which move the fingers and toes have been differentiated from one (communis) muscle. He has found many stages of differentiation. The flexor which inserts in the thumb of man inserts in two or three toes in the higher apes. The extensor of the index-finger is the same in the gorilla as in man, but in the lower apes and lemurs it has two parts. In lemurs the third finger gets a tendon from the extensor of the index. In all apes the extensor muscle of the third finger is inconstant. On the theory that the proprius muscles, the flexors and extensors of the fingers and toes, have been developed by specialization out of one communis muscle, these facts and many others of the same kind are luminous; on any other theory they are inexplicable. In the foot, man remains a creature of the past, not modified by that which makes him a man, the brain. The hand has been modified and perfected by its services to the brain.

The Orang and Man.—Dr. Barnard's paper on "The Myology of *Simia satyrus*" was based on a dissection he had made of an orang at Cornell University, and dissections of lower apes recently made in Germany. When, in 1818, Traill dissected one of the higher apes, he found a muscle which he homologized with the *gluteus minimus* (one of the abductor muscles of the thigh) in man. Other muscles in the same region he supposed to represent similar muscles in man. But one muscle he found in the ape, which he thought had no representative in man, and this he named the *scansorius*, or "climbing-muscle." Traill was followed by Owen, Wyman, Wilder, and by Bischoff, who, in his controversy with Huxley, argued from this muscle against a simian ancestry for man. Dr. Barnard shows that Traill was mistaken, and that the other great anatomists were misled by the weight of his authority. What Traill took to be the *gluteus minimus* is the *pyriformis*, and what he figured as a new muscle separating the apes from man, the *scansorius*, is the homologue of our *gluteus minimus*. In the orang, Dr. Barnard finds a muscle which has no homologue in man. It is a mere vestige. It occurs in some of the lower apes, as the lemurs, but has no functional value. It is found in the opossum, but no longer as a vestige. Thus when we go back as far as the marsupials, this muscle, which in man is obsolete, almost obsolete in the higher apes, less aborted in the lower apes, is an active organ, performing certain functions. In the *orang* the two external muscles of the calf do not unite to form one tendon, *tendon Achillis*, as in man. Now, this double tendon Achillis sometimes occurs in marsupials. These researches go far to prove that the muscles of man can be traced backward through the apes to the lemurs, and through them to the marsupials.

The Study of Mathematics.—Prof. H. A. Newton, vice-president of Section A, at the Detroit meeting, advocated in his address a wider and deeper study of mathematics by American men of science. American contributions to the science of quantity have not been large; take away from their number three or four volumes, a dozen memoirs, and here and there a fruitful idea, and there is very little left that the world will care to remember. True, excellent text-books have been made here; but Prof. Newton is speaking of additions to our knowledge and not of the arrangement of it. The idea seems to be quite general among us that the mathematics is a finished science, and that it has few fertile fields inviting labor, and few regions to be explored. And yet hardly any science can show on the whole a more steady progress for the last fifty years, or a larger and healthier growth, than the science of quantity. The scientific investigator finds himself again and again arrested in his re-

searches, for the want of sufficient knowledge of the mathematics. Hence Prof. Newton's advice to the young student in almost any branch of science is to acquire, first of all, a knowledge of geometry, analysis, and mechanics, so that the main ideas in them shall ever be familiar to him, and their processes readily recalled. Throughout the chemical and physical sciences, the laws are more and more assuming a mathematical form.

The unwisdom of neglecting the mathematics is again seen by considering some of the problems which appear to be in their nature capable of a mathematical solution. To explain by the accepted laws of rational mechanics all the forces and motions of the ultimate particles of matter, of inorganic matter even, may well be beyond the powers of the human mind. But that some of these forces and motions will be explained, even at an early day, seems to be almost certain. So the essential differences in the chemical elements may not be beyond discovery and explanation. Each line in the spectrum has its definite place, and those places are the results of certain laws of structure of the substance that gives the spectrum, and of its consequent action upon the light which comes from or traverses the substance. The time seems near for a Kepler who shall formulate those laws, and for a "Principia" which shall unite them in their most general mathematical expression. In like manner, along the line which in astronomy and physics separates the unknown from the known, there are hundreds of questions whose solution, if attained, must be in part mathematical.

Prof. Newton then speaks of the *rôle* of the laws of quantity in the sciences of political economy, geology, biology, and psychology.

Coast-Survey Measurements.—We take from the *Tribune* the following brief abstract of Prof. Hilgard's paper on "Coast-Survey Measurements." The author described the work of measuring a primary base-line near Atlanta, Georgia. The work is liable to error chiefly from changes in the temperature and instability in the apparatus. As every error in the base vitiates all succeeding measures, in which any errors are necessarily multiplied, it will be seen what care was needed to insure accuracy. The results, obtained by methods which Prof. Hilgard described at length, were tested three times by a repetition of the measurement at different seasons of the year. The greatest error thus detected was a deviation from the average of about $\frac{1}{10000000}$ part of the whole. To increase the severity of the tests, one of the measurements was made backward. Another way of stating the possible error is that it would be a third of an inch in six miles. Already this system of measurement, which is purely American, has elicited high praise abroad, and it will probably be adopted by European governments in their surveys. In previous papers before the Association the superiority of the American method for ascertaining longitudes had been expounded, and this system is now substituted for all previous ones in Europe. The apparatus used will form a part of our centennial display.

Grasshopper Dinners.—Prof. Charles V. Riley read a paper on "Locusts as Food for Man." The introductory portion of this paper was historical, tracing the use of locusts as human food to the earliest times of which there is record. Among the Nineveh sculptures are representations of men carrying different meats to a place of feasting, and some of the men are carrying sticks on which locusts are tied. In the book of Leviticus the locust is classed with "clean meats," and elsewhere in the Bible this insect is spoken of as food for man. Herodotus mentions a locust-eating tribe in Ethiopia, and Livingstone witnesses to the existence of this habit among modern African tribes. Even in the cities of Morocco, locusts are offered for sale in the markets and eating-houses. Many American tribes use this insect for food. In Southern Russia the locusts are salted and smoked; in Morocco they are boiled and then fried. Prof. Riley has had the locust cooked in a variety of ways, in order to test its flavor. This he pronounces "quite agreeable." Fried or roasted in their own oil, they have, he says, a pleasant, nutty flavor.

The Gar-Pike.—Several papers were read by Prof. Wilder, of Cornell University, who has spent the summer in the West. Of

these one was on the gar-pike. The gar-pike is known to science as a very ancient type of ganoid fish—a sort of living fossil. The young gar has two tails, the one serpent-like and the other fish-like. The former is snake-like in motion as well as in form. It is largest and most active in the very young. As the fish grows, it aborts, and at adult age it is obsolete. Prof. Wilder's investigations show that this temporary tail is a vestige, a reminiscence, a survival. The ancestor of the gar was a reptile, and the young fish still carries the ancestral reptilian tail. Another paper by the same author was on—

The Sirenia.—The name we have borrowed from Greek mythology, according to which the sirens were young maidens who sat on the shores of a certain island near Italy, and "sang with bewitching sweetness songs that allured the passing sailor to draw near, but only to meet with death." Why the manatee and the dugong should be called sirenia is not apparent on the surface, for they are not graceful, neither are they sweet singers; besides, they bear no enmity to the human race. Externally the sirenia are whale-like, but internally they are pachyderm-like. Prof. Wilder has dissected a fœtal dugong (secured in Australia by Prof. Ward), and from a study of its structure he concludes that the sirenia are not modified whales, but modified pachyderms, and that they are descended from some ancient hippopotamoid quadruped.

Porcelain-Clay.—A paper was read by Prof. Cox, Indiana State Geologist, on a white clay resembling kaolin, lately discovered in Lawrence County, Indiana. A full synopsis of this paper was published in the *Tribune*, from which we derive the following particulars: The Lawrecne County bed of porcelain-clay occupies the position of the Archimedes limestone belonging to the Chester group. This limestone has been entirely removed where the clay is found, by the action of water charged with hydrated silicate of alumina and carbonate of protoxide of iron. The water which held these substances in solution is supposed to have contained alkaline carbonates, with carbonic acid in excess. It is thus that the water was enabled to dissolve the limestone, and by an interchange of chemical constituents, the hydrated silicate of alumina was precipitated and the lime carried off in solution. The carbonate of protoxide of iron also continued in solution until it met with a sufficient amount of oxygen for its peroxidation and precipitation. The upper portion of the clay, from one to twelve inches in thickness, is of a light cream-color, free from grit and laminated. Then follow from four to five feet of pure white clay, also free from grit. Beneath this is a clay of similar quality, but slightly stained at the joints with oxide of iron. Prof. Cox calls the white clay *Indianaite;* it has a composition of 12 to 14 per cent. water, 42 to 45 per cent. silica, and 36 to 39 alumina. The area of the deposit is known to be at least 42 acres, and there is little doubt that it is much more extended. Indianaite is now used in the porcelain potteries at Cincinnati, and ware made of it is fully equal to the best English ironstone pottery.

Are Potato-Bugs poisonous?—A paper by Augustus R. Grote and Adolph Kayser stated the results of an investigation of the supposed poisonous properties of the potato-bug. A quantity of the bugs were submitted to distillation with salt-water, so as to increase the temperature, the product being four ounces of liquid from one quart-measure of the bugs. This liquid had an alkaline reaction, owing to the presence of free ammonia and carbonate of ammonia. It was perfectly clear, and had a very offensive odor. A tincture of the *doryphora* was next prepared, the bugs having been digested for twenty-four hours in alcohol, which was then evaporated at a gentle heat. The tincture had a decided acid reaction, was brown in color, odor not offensive. On introducing into the stomach of a frog about half a cubic centimetre of the liquid and of the tincture separately, no effect was observed. Hypodermic injection of the distilled liquid was in like manner unattended by injurious results, but the tincture proved fatal when administered in this way. The leg, into which the tincture was injected, was quickly paralyzed, and in thirty minutes the heart had ceased to beat. This tincture, though highly concentrated, con-

tained but a minute quantity of animal acids, of composition analogous to those secreted by the flea or the bed-bug. In the insect last named there are special organs for the secretion of these acids, but no such organs have been found in the potato-bug. The conclusion reached by the authors is, that the potato-bug is not poisonous, and that the cases on record of poisoning supposed to be caused by the bug are in fact traceable to Paris-green.

In the discussion which followed the reading of this paper, Prof. Riley said that his own investigations had satisfied him of the poisonous properties of the *doryphora*. "Experiments on frogs," said he, "are not conclusive. Some people are far more sensitive than others to poisonous influences; and much greater differences are to be expected to exist between man and reptiles in this respect." Prof. Cook stated the results of a series of experiments which he too had made on frogs. He starved the frogs before administering to them a decoction of potato-bugs, and the effect on the reptiles was to make them very sick.

Chemistry.—A number of chemical papers were contributed by Prof. J. Lawrence Smith. One of these was descriptive of an apparatus for exhibiting the absorption of gases by palladium. The apparatus consists of slips of palladium and platinum; on being introduced into a flame, the palladium-slips coil up like a scroll, while the platinum-slips retain their original form. Another paper was on "Graphite Oxide, as prepared from the Graphites of the Sevier County Meteoric Iron, and DeKalb County Meteoric Iron." Further, he exhibited a pound-weight of cæsium alum. He gave an account of his unsuccessful attempts to obtain cæsium in the pure state. Small particles of the metal were obtained mixed largely with a carbonaceous compound, but they could not be detached from the black mass, as they took fire on being exposed to the atmosphere.

Meteorology.—A new meteorological instrument, designed to measure the effects of various climatic conditions on the human body, was described by John W. Osborne, of Washington. The instrument has a motive power, furnished by a clock, which agitates two pounds of water heated to the temperature of the blood. The water is contained in a paper vessel which permits some evaporation. The water for these experiments was heated somewhat above blood-heat, for quickness in registering and reading. The vessel containing the heated water represents the human body, and the effects of heat, cold, wind, and moisture, can be measured just as they affect the human body, and thus the precise extent of these changes can be registered and formulated.

Velocity of Electricity.—We take from the *New York Times* the following abstract of Prof. Joseph Lovering's paper on "An Acoustic Method of measuring the Velocity of Electricity." Practically, he said, electricity has no velocity. According to one experiment, when a very long conductor was used, electricity traveled at the rate of 288,000 miles per second. This rapidity is considerably lessened when a shorter conductor is used, and may come down to barely 800 miles per second. For satisfactory experiment, therefore, the longest possible lines should be used. A wire from Cambridge, Massachusetts, to San Francisco, and thence back through Canada to Massachusetts, about 7,200 miles in all, transmitted a message in two-thirds of a second, and some of this time was wasted through thirteen repeaters. Electricity traveled over 4,000 miles of cable in one second, even under some unfavorable conditions. Prof. Lovering's system connects the wire with tuning-forks, the vibrations of which indicate the ten-thousandth part of a second, or even less. The application can be made, however, only by those who are familiar with acoustics.

Transportation of Fish-Eggs.—A recent shipment of salmon-eggs from Glasgow to New Zealand was unsuccessful. The cause of this failure is not known, as every precaution was taken by Mr. Frank Buckland, who superintended the shipment, to insure success. The length of time, says *Nature*, during which the eggs were packed on board ship was one hundred and twenty-one days, or only nine days longer than the

period during which it has already been proved by Mr. Buckland and Mr. Youl that the development of salmon may be safely retarded by ice. A large quantity of the ice surrounding the ova remained till the end of the voyage, so that the temperature of the ice-houses must have been kept very low throughout the voyage. The cases in which they were packed are described as "sodden," so that they did not suffer from dryness. Probably want of ventilation caused the failure of the experiment.

Ancient Glaciers of the Sierra Nevada at Lake Tahoe.—In the *American Journal of Science* for August is an interesting paper, by Prof. Joseph Le Conte, on the ancient "Glaciers of Lake Valley," in which is situated the well-known and beautiful Lake Tahoe. The great glacier which filled all the lower part of the valley had its source in the snow-fountains among the mountain-peaks at its southern end. The valley is a trough between two ridges of mountains near the top of the Sierras. It is 20 miles wide, 50 miles long from north to south, and is 3,000 to 3,500 feet deep; its lower half is filled with the waters of Lake Tahoe. This lake occupies an area of about 250 square miles, and is 1,640 feet deep.

On either side of the lake are mountains, but those which still show best the glacial sculpturings are on the westerly side. Some of these rise 3,000 feet above the level of the lake, and are between 9,000 and 10,000 feet above the level of the sea. The surface of the lake is at nearly as great an elevation above tide as the summit of Mount Washington. The ice at its greatest development filled the valley—a vast *mer de glace*—to a height of 300 or 400 feet above the present lake-level, and was therefore about 2,000 feet thick. It moved northward, and was discharged upon the plains; some of it evidently moved down the cañon through which the Truckee River now flows.

This glacier was fed by tributaries from the mountains, and these continued to flow after the great *mer de glace* had ceased to exist. Enormous mounds of *débris*, glacial *moraines*, occur between the lake-margin and the mountains, cut with wonderful regularity by water; and toward the southwestern portion of the lake occur those exquisite lakelets which add to the charm of the region. Of these, Fallen Leaf Lake, Cascade Lake, and Emerald Bay, are of wonderful beauty. The green waters of Emerald Bay contrast with the clear blue waters of Lake Tahoe. Lake Valley, in which Lake Tahoe lies, may not have been wholly scooped out by glacial action. Prof. Le Conte suggests that an area of depression may have been formed in the process of elevation of the mountains, which was enlarged and deepened by erosion.

American Grape-Vines and the Phylloxera.—Four years ago Prof. Riley went to France to study, on the spot, the grape-*Phylloxera*. Some of the scientific results of this visit—as the establishment of the identity of the European insect with that found in our own vineyards, and the American origin of the *Phylloxera*—are known to our readers; but the practical results are highly interesting and important. His experience, here, having taught him that some of our indigenous vines offered greater resistance to the insect than the European varieties, and that, with European vines, there was no hope of discovering a remedy which would prove practicable and satisfactory on a large scale, and under all conditions, he advised the French grape-growers, as one of the most promising means of restoring the ravaged vineyards, to import American vines, either for their fruit or as stocks for the French varieties. Results are fast justifying this advice. The insect continues to broaden the area of its devastations; and in many sections of Southern France, where but a few years ago the whole country was one great vineyard, the ground is now either entirely or partly devoted to other crops, to which it is poorly suited, or the vineyards are rapidly perishing. In spite of the large national reward for a remedy—in spite of the well-directed and persistent efforts of the government, and of the Academy of Science, to discover one—nothing but submersion, which is practicable to but a limited extent, proves effectual, and by degrees the fact is being acknowledged that all other remedies are futile. The American vines, however, are fast gaining ground, and the people begin to look to them as a means

of restoring their blighted vineyards. From a few rooted plants selected by Prof. Riley, and sent over four years ago to Gaston Bazille, then President of the Central Agricultural Society of Hérault, the demand increased each year, until in 1874 it reached many millions, and we have the curious spectacle of a large exportation of American vines to a country that has hitherto despised them as unworthy of culture. We see from some of the French papers that Prof. Riley has this summer revisited the south of France, and that he has found the American vines flourishing in the midst of the dying and dead French vines, and in the order of the varieties recommended four years ago. To testify their appreciation of his services, the Central Society of Agriculture of the department of Hérault held an extraordinary session at Montpellier, and gave a grand banquet at Palavas, in his honor.

Formation of Hail in the Spray of Yosemite Fall.—The *American Journal of Science* for September contains an interesting article, by Prof. Brewer, on the formation of hail in the spray of the Upper Yosemite Fall, as observed by himself on the 14th of April last. This magnificent fall is 1,550 feet high, and at the time, the stream being swollen by rains and melting snow, leaped clear from the rocks into the air and was soon torn into spray. "It seemed," says the professor, "as mobile as smoke, and assumed new varieties of outlines each instant, so light and airy that it seemed as easily swayed by wind as lace, yet it struck with deafening thunder. The concussion was perceptible through the granite for some distance." The discharge of water was estimated at 250 to 300 cubic feet each second.

The water in winter falls behind a great cone of ice which forms from 100 to 200 feet in thickness, and emerging beneath the ice a grand arch is formed like that in the glacier at Mont Blanc, whence the Arveiron flows. Standing at the foot of this upper fall, a thousand feet above the bottom of the valley, Prof. Brewer and his companions felt, in the violent tempest of spray, ice-pellets or *hail* which stung their hands and faces like shot. They fell in considerable quantity, rapidly melting, for the sun shone full on the fall, and the rocks around reflected the heat. The diameter of some of the pellets was estimated at one-tenth of an inch.

Here we have the spray of the water-fall condensed and frozen into hail. The process by which this may occur is clearly stated by Prof. Brewer.

The water, supplied from melting snow, plunges over the cliff at just about the temperature of freezing. "In the fall it appears to be 'atomized' for 1,200 or 1,400 feet of its descent. A great volume of air is drawn into this falling mass along its whole course, the sheet spreading as it descends. The quantity of air is so great that it pours outward on the bottom of the valley and is very perceptible as a cool current more than a mile distant from the base of the upper fall. The air as sucked into the fall is immediately cooled to 32° by the ice-cold water. As it passes in, it is very dry, and the rapid saturation within the sheet is sufficient to freeze a portion of the drops."

Distribution of Temperature on the Solar Disk.—From the researches of Prof. Langley, referred to last month in the abstract of Secchi's observations on sun-spots, it appears that, though the nucleus of a spot is much cooler than the surface surrounding it, there is no great difference of temperature between it and the photosphere near the sun's limb, though the difference in brightness is so considerable. In fact, Mr. Langley has shown that the relatively black nucleus actually radiates more heat than the bright photosphere quite close to the limb. Following up this discovery, he has shown that the absorption of light, both in the case of a spot, and of the parts of the sun's surface near the limb, is not accompanied by a *corresponding* absorption of all the heat-rays (invisible as well as visible), so that, taking Sir W. Herschel's estimate of the brightness of the nucleus as $\frac{7}{1000}$ of that of the photosphere, Mr. Langley finds that we receive from a spot fifty times as much heat as light, and a similar conclusion is arrived at with reference to the surface near the limb. On comparing the equatorial and polar regions, no appreciable difference was observed in the heat received.

How this is accounted for by Secchi was stated in the September number.

Prof. Mayer, of the Stevens Technological Institute, adopts a different method of observation, and his results differ considerably from those both of Langley and of Secchi. He causes the image of the sun to fall on the smoked surface of a thin sheet of paper, while the other side of the paper is coated with a film of Meusel's double iodide of copper and mercury. He begins with an aperture of object-glass, which does not give sufficient heat in any part of the solar image to blacken the iodide, gradually increasing the aperture till he gets a well-defined blackened area. This is the area of maximum temperature. The aperture being further increased, the blackened surface extends, and a new area is formed bounded by a well-defined isothermal line. This process is continued till the isothermals of the entire image are mapped out.

Prof. Mayer finds that—1. There exists in the solar image an area of sensibly uniform temperature and of maximum intensity. 2. That this area is *of variable size*. 3. That it *has a motion* on the solar image. 4. That it is surrounded by well-defined isothermals. 5. That the general motions of translation and of rotation of these isothermals appear to follow the motions of the area of maximum temperature, but that both central area and isothermals have *independent motions of their own*.

One-sided Development.—In an article entitled "Lop-sided Generations," published in the *Journal of Anatomy and Physiology*, Dr. Hollis points out the existence of the habit of using the right hand in preference to the left among those peoples whose monuments date from the remotest antiquity. What is the reason of this almost universal fact? The author turns to the anatomical mechanism of the human body for an answer. It is known that the right lung, liver-lobe, and limbs, exceed in size those of the left side, involving, of course, a greater amount of tissue-structure, and a larger supply of nerves and blood-vessels for their nutrition. A person walking in a dense fog figures with his feet the segment of a circle; and, if he is right-handed, he takes a direction to the left, because the right leg naturally takes a longer stride. The left side of the brain is larger than the right; it has been shown that the power of verbal articulation in the right-handed is confined to a certain convolution on the left side; and hence we arrive at the fact that in speaking and thinking we use the left side of our brain, this being the result of dextral education. Amnesia and aphasia in right-handed men indicate disease of the left brain. Hammer-palsy and writer's cramp show the results of excessive working of the left brain. Dr. Hollis insists on the necessity of adopting a system of education which will give an equal prominence to both sides of the brain in all intellectual operations.

The Tribes of Western Australia.—Mr. John Forrest, of the British Anthropological Institute, in giving an account of the natives of Western Australia, states that they are divided into two great tribes, Jornderuss and Ballavook, which are again divided into innumerable sub-tribes. These great tribes are exogamous: a Jornderuss may not marry a Jornderuss, but must take a Ballavook. Wife-stealing is a constant source of quarreling among them, and the women are frequently speared or killed. The children belong to the mother's tribe. Tattooing and marking on the shoulder and breast are almost universal among these tribes. The rite of circumcision is practised by all the tribes that Mr. Forrest met with, except those of the southwest corner of Australia. It is a religious ceremony, and the men and women part for a fortnight upon the occasion of it. The natives of the interior are entirely without clothing, and suffer much from the cold. They sleep in the open air, except in wet weather, when they build small huts. Cannibalism is common in the interior.

Science allaying National Antipathies.—The *Edinburgh Review* expresses the opinion that the study of two sciences, namely, comparative philology and ancient law, has already done much, and is destined to do still more, to bring about an understanding between the people of Ireland and of England. Comparative philology proves, beyond doubt, the connection of the Saxon and Celtic people; and indicates, in a gen-

eral way, that these two branches of the Aryan stem were united during a great part of their history. It was left, however, to ancient law to solve the problem with more completeness, and to determine more clearly the place of Ireland in the great aggregate of Aryan nations. The preface to the third volume of the recently-published Irish "Brehon Tracts" gives a clear account of the development of the ancient laws of Ireland, of their relation with kindred Aryan usages, and of the social life that is reflected in them. Sir Henry Maine, too, has demonstrated that the native laws of Ireland are a mass of archaic Aryan customs. "He has shown that the old forms of Irish life, which he has reconstructed with marvelous skill, have a most striking and curious analogy to those of older races of Aryan descent, in various stages of growth and progress; and he has thus established the true inference, that the supposed barbarism of the Irish people is simply a conceit of undiscerning ignorance; that we may regard Ireland as a plant, of which the development has been checked and arrested, but that she is of the same stock as ourselves; and that we must seek the causes of her misfortunes in circumstances independent of race."

A Snake-eating Snake.—One of the recent accessions to the population of the London Zoölogical Gardens is a specimen of the *Ophiophagus elaps*, the snake-eating snake. The new-comer has been described by Frank Buckland, who represents him as a very formidable type of ophidian. In length he measures over seven feet; circumference about equal to the thickness of a man's wrist. His virus is as deadly as that of the cobra, and he is, moreover, a regular athlete among snakes. His head is very lizard-like and harmless-looking—not flat and triangular as is the head of the puff-adder, the rattlesnake, or the viper. He has an intelligent eye. Like the cobra, he has a hood which he can expand when angry, and his body is ornamented with very pretty stripes. His mode of attack is peculiar: he glides after you with the swiftness of a hawk after a bird, and when he gets up to his enemy bites him and retires. He is, therefore, more to be feared than the lion, the elephant, or the boa-constrictor; one slight prick, quick as an arrow, of the poison-fang, and the life of the man ebbs out of a minute hole in the skin that would barely admit a needle's point. On his arrival at the gardens the *Ophiophagus* was treated to a live English snake, which he instantly seized and swallowed head foremost.

Mr. Buckland ascribes to Fayrer the credit of having given "the only correct account of this creature's habits, especially that of his eating other snakes." But herein he is corrected by Surgeon-General Stewart, who states, in *Science Gossip*, that *Ophiophagus elaps* was discovered by Dr. Theodore Cantor, of the Bengal Medical Service, who described the animal and its habits more than thirty years ago under the name of *Hamadryas ophiophagus* in the *Journal of the Asiatic Society of Bengal*. Surgeon Stewart gives some of his own recollections of the behavior of this serpent, while he observed it in company with Dr. Cantor. He says that it devours rats, mice, and small birds. Once Cantor offered a bandicoot to a *Hamadryas*. The former showed fight, and the latter seemed to be afraid, so the bandicoot was knocked on the head, and so probably the life of the snake was saved.

Prevention of the Effects of Bee-Sting.—From a letter in the *British Bee Journal*, by Mr. G. Walker, it appears that immunity from the pain and other injurious effects of the sting of the bee may be gained by inoculation with the virus of that insect. Mr. Walker allowed a bee to sting him upon the wrist, taking care that he received the largest amount of poison, by preventing the bee from going away at once; then he let the poison-bag work, which it does for some time after being separated from the bee. The first day he was stung twice. The effect was rather severe cutaneous erysipelas, disorder of the motor nerve, with the usual signs of inflammation. A few days having elapsed, and the symptoms having subsided, he caused himself to be stung again three times in quick succession. The attack of erysipelas was on this occasion not nearly so severe, still a stinging sensation ran up to the shoulder, and a lymphatic gland behind the ear increased considerably in size, the poison being taken up by the lymphatic system. A few days subse-

quently he was stung thrice, and the pain was considerably less, though the swelling was still extensive. At the end of the next week he had had eighteen stings, and by the close of the third week thirty-two stings. After the twentieth sting there was very little swelling or pain, only a slight itching sensation, with a small amount of inflammation in the immediate neighborhood of the part stung, which did not spread farther.

Influence of Cobra-Poison on Ciliary Action.—In the *Monthly Microscopical Journal* for June is given a record of experiments made by Drs. Brunton and Fayrer upon the influence of cobra-poison on ciliary action. Ciliated epithelium from a frog's mouth was treated with a solution of the poison, and examined under the microscope. The cilia were then in vigorous action. Ten minutes later this action was much diminished, and in twenty minutes it had ceased. Again, ciliated epithelium was placed under the microscope, one part being treated with water and the other with the poisoned solution. Ciliary action was at first vigorous in both, perhaps more so in that subjected to the poisoned solution. Eight minutes later, non-poisoned cilia still active, poisoned cilia very feeble. Ten minutes, non-poisoned cilia still active, poisoned very feeble. Fourteen minutes, non-poisoned cilia still active, poisoned cilia very languid. Twenty minutes, non-poisoned cilia still active, poisoned cilia perfectly inactive. From this it is evident that the poison first stimulates and then destroys the activity of the cilia.

The action of the poison on vegetable protoplasm is very different. This subject was investigated by Mr. Darwin, who tested the action of cobra-poison on *Drosera*. A minute drop of the solution (one-quarter grain to two ounces water) acted powerfully on several glands of the drosera-leaf—more powerfully than fresh poison from an adder's fang. On immersing three leaves in ninety minims of the solution, the tentacles soon became inflated and the glands quite white, as by the action of boiling water. The leaves appeared to be killed, yet after eight hours' immersion they were placed in water, and after about forty-eight hours re-expanded. Having immersed a leaf in the solution for forty-eight hours, Mr. Darwin found that the protoplasm was then incessantly changing form, being unusually active. "Hence," says he, "I cannot doubt that this poison is a stimulant to the protoplasm" of plants.

Copper-poisoned Pastures.—It was observed by the late Prof. Buckland, the geologist, that the bones of cattle pastured in the vicinity of copper-works became diseased. This observation has been confirmed by his son, Frank Buckland, who has examined the skull of a cow, which had for three years grazed the copper-smoked grass. He describes the substance of the bone as much thickened and enlarged. Instead of the usual ivory-like smooth appearance of healthy bone, it appears to be eaten into minute pits. The lower jaw presents several hard, osseous excrescences, and the general appearance closely resembles that of bones affected by mercurial poisoning, one of the symptoms of which is a superficial deposit of rough, porous bone. Whether the mineral deposited on the grass in the vicinity of copper-works, and which is eaten by cattle, and subsequently absorbed into their system, be copper or arsenic, or arsenite of copper, Mr. Buckland is unable to determine at present, but he intends to have the substance analyzed by a competent chemist. The symptoms of the poisoning are stated as follows by a correspondent of Mr. Buckland: First, the beast appears dull, and its hair is dry; the eyes water, and the belly becomes tucked up; soon the beast shows signs of being in pain when moved; hard lumps rise on the legs and on the ribs; the bones of the head become enlarged, and the eyes appear sunken; the teeth become black and worn; lameness appears, sometimes in one leg only, at other times in all the limbs; in milch-cows the milk dries up.

Sensitiveness of Silver-Salts to Light.—In the *American Journal of Science*, for April, M. Carey Lea has a paper on "The Action of the Less Refrangible Rays of Light on Silver Iodide and Silver Bromide," in which the following propositions are maintained, viz.: 1. That these two salts of silver are sensitive to all the visible rays of the spectrum; 2. That silver iodide is more

sensitive than silver bromide to all the less refrangible rays, and also to white light; 3. That the sensitiveness of the bromide to the green rays is materially increased by the presence of free silver nitrate; 4. That bromide and iodide of silver together are more sensitive to both the green and the red rays (and probably to all the rays) than either the bromide or the iodide separately; 5. That, contrary to Becquerel's theory, there do not exist any rays with a special exciting or a special continuing power, but that all the colored rays are capable both of commencing and continuing the impression on silver iodide and bromide.

NOTES.

THE Acclimatization Society of Cincinnati has had printed muslin handbills offering a reward of ten dollars for "any information that will convict persons of violating" in the vicinity of that city "the laws framed for the protecting of birds."

THE Prussian Government offers a prize of 3,000 marks (about $700) for a method which will give plaster-casts the power of resisting periodically repeated washings, without injuring in the least the delicacy of the form, or the tint of the plaster. Also a prize of 10,000 marks (about $2,500) for a material for making plaster-casts of artworks, possessing the advantages of plaster, but which, without any special preparation, will not deteriorate by periodically-repeated washings. The conditions of competition are stated in full in the *Journal of the Society of Arts*, No. 1,177.

FROM official returns published in the *Sanitarian*, it appears that in the city of Boston there occurred, in the year 1874, 11,717 births, whereof 6,021 were of males and 5,696 of females. The proportion is as one to 28.27 of population. Of the whole number 54.74 per cent. were of foreign parentage by both parents; 66.35 per cent. had foreign-born fathers; 73 per cent. were of parents one or both of whom were foreign-born. Of Irish parentage there was one birth to 20.05 of the population; of native, one to 73.24.

MODOO SOODUN GOOPTA is the name of the first Hindoo that ever dissected a human cadaver; this he did in 1836. Still not till seventeen years later did scientific medicine begin to find favor among the natives of India. At present students in great numbers attend the medical colleges of Calcutta, Madras, Bombay, Agra, and the schools of Lahore and Nagpoor.

DURING the whole month of June, according to the Monthly Weather Report, vessels navigating the North Atlantic were in danger from ice-drift and icebergs. The steamship Scandinavian, while off the coast of Newfoundland, on the 29th of June, sighted no less than 100 icebergs, many of them of monstrous size.

CAPTAIN LAWSON, whose book, "Wanderings in New Guinea," is almost universally considered to be a work of fiction, on June 22d read a paper at the London Anthropological Institute on "The Papuans of New Guinea." Before the paper was read several members urged the chairman to require of the author some evidence of his good faith, but the motion was overruled, and Captain Lawson was allowed to proceed. In the discussion which followed, Dr. Busk and others expressed opinions adverse to the author's credibility, and the usual vote of thanks was not passed.

THE *Tribune*, of Salt Lake City, announces the discovery in North Mill Creek Cañon, near the line of the Utah Central Railroad, of a rich mine of mica. The belt is said to be about 1,000 feet wide and 1,000 feet long. Sheets of mica three by four inches can be obtained in abundance, and development of the mines will doubtless open beds from which sheets of any size can be taken.

A TRAVELER in Zanzibar states that in that country ants are a great pest. They move along the roads in masses so dense that beasts of burden refuse to step among them. If a traveler should fail to see them coming in time to make his escape, he soon finds them swarming about his person. Sometimes, too, they ascend the trees and drop on the wayfarer.

THE telegraphic cable between Anglesea and Ireland was recently taken up for the purpose of repairing a fault which had occurred not far from the former island. The fault was found to have been caused by a minute crustacean (*Limnoria terebrans*), which had pierced the gutta-percha covering of the cable. The application of creosote seems to be the only preventive of the depredations of this little creature.

A HIGHLY-IMPROBABLE story is published in the English newspapers, of the discovery in Syria of a large number of villages, the names of which are unknown to the geographer, and even to the tax-gatherer. No fewer than seventy-nine of these hapless hamlets, so the story runs, have been unearthed in the single district of Damascus, besides about an equal number in other parts of the province, by Medjeddin Effendi, who has been devoting his time and energies to the exploration of old official regis-

ters. He is still, it is stated, busily employed in prosecuting his researches, and it is strongly suspected that a number of other unknown villages will be dragged to light.

DIED, June 14th, Prof. Henry d'Arrest, of the University of Copenhagen, aged fifty-three years. The Royal Astronomical Society of England last February awarded to Prof. d'Arrest a gold medal for his "Catalogue of the Nebulæ." At the time of his death he had just completed and published his spectroscopic survey of the northern heavens.

WE published a note in the July POPULAR SCIENCE MONTHLY, on the authority of the *Sanitarian*, giving the annual death-rates of several American cities, as deduced from the mortality of the month of March last. That of the city of Nashville was represented as the highest of the places mentioned, its death-rate being set down at 37.69 per thousand per annum. This was a grave mistake, which it is both a duty and a pleasure to correct. It appears from official documents sent us by the authorities of that city, and based on carefully-collected data, that the mortality in March gives a death-rate of only 26.27 per thousand, a figure considerably below that of several of the other cities named.

AT the meeting of the American Association a report was submitted by Prof. Newton on weights and measures. It is there stated that the leading powers of the world have called for a convention during the present year, to provide for the creation and maintenance, in the city of Paris, of an organization to be known as the International Bureau of Verification. This bureau will be charged with the distribution, to the governments of the powers represented, of accurate standards of measurement. The report also contains resolutions providing for a memorial to Congress requesting an appropriation to provide for the expense of commissioners from the United States. These resolutions were unanimously adopted by the Association.

M. BÉRENGER-FERAUD, surgeon in the French naval service, notes a singular custom which he found existing among the Balantes, a tribe dwelling on the banks of the Casamanca, in intertropical Africa. They make the duration of marriage responsibilities dependent on the conservation of the *pagua*, or festive garment given to the wife by the husband on the occasion of their wedding. The woman who wishes to be divorced from her lord has merely to wear out her *pagua* as fast as possible, and then present it in a tattered condition to her family, whereupon she obtains release from the power of her husband.

THE Smithsonian Institution and the Indian Bureau are forming a large collection of crania, ornaments, utensils, weapons, pottery, and the like, illustrative of the ethnology and archæology of North America, which will form a department of the Centennial Exposition at Philadelphia. At the late meeting of the American Association a resolution was adopted inviting the International Congress of Prehistoric Archæologists to hold their meeting of next year in the United States. The delegates to the Congress would find, in the collection mentioned above, an abundance of material which could not fail to throw light upon many of the obscure problems of the early history of mankind.

IN examining the surface-mud of a shallow rain-water pool, Prof. Leidy observed the movements of a multitude of microscopic algæ, which he referred to the species *Navicula radiosa*. These diatoms were very active, gliding hither and thither, and knocking the quartz-sand grains about. Comparative measurements showed that the naviculæ could move grains of sand as much as twenty-five times their own superficial area, and probably fifty times their own bulk and weight, or perhaps more.

PROF. RAMSAY is of the opinion that in pre-Miocene times the Alps were probably higher than they are now, notwithstanding the fact that their present elevation is due to subsequent upheaval. That the Alps suffered very extensive denudation during the Miocene period he finds amply demonstrated by the enormous thickness of fresh-water and marine deposits of Miocene age, now spread over Switzerland, these deposits having been formed by the degradation of the pre-Miocene Alps. An elevation of upward of 5,000 feet took place after the deposition of these strata, but the Alps continued to suffer denudation during the Pliocene and post-Pliocene ages, although it is difficult to estimate the extent of this loss.

A FUNGUS, belonging to one genus with the *Peronospora infestans* of the potato, is at present ravaging the opium-poppy in India. This fungus (*Peronospora arborescens*) is invariably found in the blighted leaves of the poppy. After the parasite has done its work, the leaves of the plant become infested with several other fungi, chiefly *saprophytes*.

THE leaves of *Eucalyptus globulus* contain an ethereal oil, of which even half-dried leaves contain 6 per cent., and, according to Gimbert, this oil is a very powerful antiseptic. It will preserve blood and pus as long as carbolic acid, and far longer than oil of turpentine. It prevents also the appearance of fungi and vibrios.

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